JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. SEPTEMBER, 1882. No. 3.

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ON A NEWLY DISCOVERED ABSOLUTE LIMIT TO ECONOMICAL EXPANSION IN THE STEAM ENGINE AND IN OTHER HEAT-MOTORS.

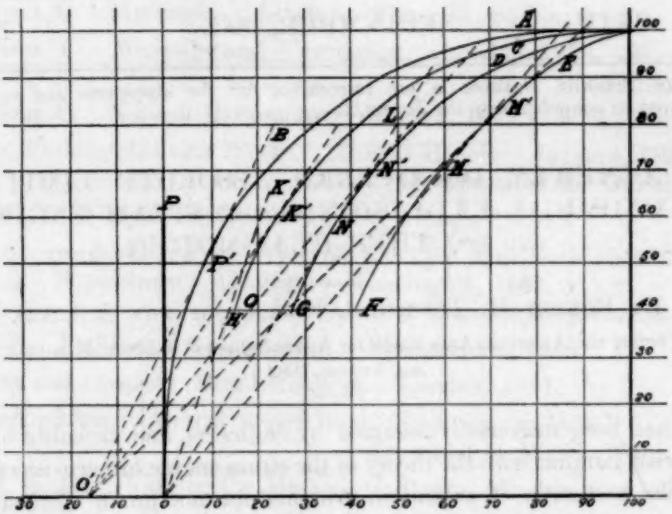
BY ROBERT H. THURSTON, FELLOW OF THE A.A.A.S.

[Read before the American Association for Advancement of Science, Montreal Meeting, August, 1882.]

It has been universally assumed by engineers, and probably by all physicists familiar with the theory of the steam engine hitherto accepted, that the best ratio of expansion, whether for maximum efficiency of fluid, of engine, of capital, or of plant,* increases with increase of steam pressure without limit, and that such ratio may be indefinitely increased with decrease of the ratio of back-pressure to initial pressure for any one kind of engine, notwithstanding the fact that the value of the ratio of expansion is modified by variation of the conditions of working, even where the ratio $\frac{p_b}{b_1}$ is the same. The writer now proposes to show that, in every actual engine, in every engine operated

* *Vide* a paper "On the Several Efficiencies of the Steam Engine," etc., JOURNAL OF THE FRANKLIN INSTITUTE, May and June, 1882; *Transactions of the American Society of Mechanical Engineers*, 1882.

under the conditions of real work and of usual practice, there exists a limiting value of any of these "ratios of maximum efficiency" beyond which it cannot be economically raised even with an infinitely elevated boiler-pressure. It will be further shown that this "absolute limit" may be readily, and probably often is, passed in every-day practice, that in the usual forms of steam engine an absolute limit exists within or not far beyond the customary working range of expansion, beyond which expansion cannot be carried with economy however high steam pressure may be adopted; in other words, with infinite pressure, the economical value of the ratio of expansion will be found often not merely finite, but sometimes probably within the limits of familiar practice.



CURVES OF EFFICIENCY

In earlier papers* the writer has shown that the conditions under which engines are worked in actual practice differ in a very important degree from those assumed in the simple thermo-dynamic theory of heat engines, and, especially, that the unjacketed steam cylinder, which is usually assumed to be of non-conducting material, is to such a serious extent a reservoir and a transferrer of waste heat that the efficiency of the engine is greatly and sometimes enormously reduced.

* JOURNAL OF THE FRANKLIN INSTITUTE, May, 1881, February, May, and June 1882; *Transactions of the American Society of Mechanical Engineers*, 1881–2.

The equations which would give values of the ratios of maximum efficiency for the ideal "perfect engine," therefore, do not apply to real engines, and the author has deduced* modified equations, which are at least approximately correct for real practice. He has also produced true "curves of efficiency" from real engines, which were found to be practically the same in form and location, to be practically identical in character with those inductively obtained, so far as the two could be compared.

These curves have the equation

$$\frac{y}{x} = b^2\, r^{2q}\, \frac{n - r^{1-n}}{n-1}$$

in which b is a constant factor; r is the ratio of expansion and a function of x; q is an exponent dependent upon the variation of cylinder-condensation with the rate of expansion; and n is the exponent of v in the approximate equations of pressures and volumes $p\,v^n$ = constant = $p_1\, v_1^n$.

When $b = 1$ and $q = 0$, the equation presented above reduces to

$$y = x\, \frac{n - r^{1-n}}{n-1};$$

which is the equation of the curve of efficiency for adiabatic expansion. The value of b usually falls between 0·8 and 0·9 and that of q between — 0·3 and — 0·1, sometimes becoming nearly 0.

In this new theory of the steam engine, it is seen, the quantity of steam used is to be calculated as for adiabatic expansion, and the amount thus given multiplied by $\frac{1}{b\, r^{-q}}$ to obtain the quantity actually demanded in non-adiabatic expansion.

The work done per stroke or per unit of weight of steam being calculated for the adiabatic case

$$W_a = p_1\, v_1\, \frac{n - r^{1-n}}{n-1},$$

it is obtained for real engines by multiplying by the factor $b\, r^q$, and we have for net work done,

$$W_n = {}_{p_b}{}^{1}\; v_1\, \frac{n\, r^q - r^{1-n+q}}{n-1} - p_b\, r\, v_1 = \frac{b\, p_1\, v_2\, n\, r^{q-1} - r^{q-n}}{n-1} - p_b\, v_2.$$

* "On the Several Efficiencies of the Steam Engine," etc.

The actual efficiency of any engine thus is less than that calculated for the ideal case in the proportion of $b\,r^q$ to 1.

THE "GENERAL EQUATION OF STEAM ENGINE EFFICIENCY," as the writer has called it, was shown to be obtained by determining the ratio of the total of annual variable costs to the power obtained from the engine

$$\frac{1}{E} = \frac{A\,r\,v_1 + B\,v}{2\,R\,W_n} = \frac{A\,v_2 + B\,v_2\,r^{-1}}{2\,R\,W_n}$$

which is a minimum when $\frac{M + r^{-1}}{W_n}$ is a minimum, A being the measure of annual costs, variable with volume of steam supplied, and $M = \frac{A}{B}$. W_n is the work done per stroke of the engine and R the number of revolutions per annum.

The value of W_n may be obtained by multiplying the value of W_a for adiabatic expansion, such as would be obtained in a non-conducting cylinder, by a factor variable with the ratio of expansion, as has been shown, which shall measure the ratio of actual work done in the metal cylinder to that done in adiabatic expansion, thus: Let b represent the proportion of steam present when expansion commences, as determined by the amount of cylinder condensation; let r^q represent the rate of variation of losses with increase of the ratio of expansion; and let n be the index for the actual expansion line of the mixture, to be determined, if possible, by experiment. Then we shall have:

$$W_n = 2\,R\left(b\,p_1\,v_2\,\frac{n\,r^{-1} - r^{-n}}{n-1}\,r^q - p_b\,v_2\right)$$

"THE GENERAL EQUATION OF ALL STEAM ENGINE EFFICIENCIES," is therefore

$$\frac{1}{E} = \frac{A\,v_2 + B\,v_2\,r^{-1}}{2\,R\left(b\,p_1\,v_2\,\frac{n\,r^{-1} - r^{-n}}{n-1}\,r^q - p_b\,v_2\right)} \qquad (A)$$

which becomes a minimum, and makes the *commercial efficiency* of an engine doing the required work a maximum when, to obtain r, we have made

$$r^q + \frac{q}{M(q-1)}\,r^{q-1} - \frac{q-n}{n\,(q-1)}\,r^{q-n+1} - \frac{q-n+1}{M\,n\,(q-1)}\,r^{q-n} = \frac{n-1}{M\,n\,b\,(q-1)}\,\frac{p_b}{p_1} \qquad (B)$$

The ratio $\frac{p_b}{p_1}$ is the quotient of the total back pressure by initial pressure, all useless resistance being included in p_b.

When instead of M, N is inserted in the equation, N being the quotient of *all* annual expenses, independent of fuel supply, by all such expenses variable with fuel and steam supply — the expression determines the ratio of expansion at "maximum efficiency of capital invested in a *given plant*."

When M or N is made zero, the expression reduces to:

$$\left(r^{q-1} - \frac{q+1-n}{q\,n}\, r^{q-n}\right) \div \frac{n-1}{b\,q\,n} = \frac{p_b}{p_1} \qquad \text{(C)}$$

and gives the ratio of expansion at which maximum "duty" or "efficiency of engine" is attained.

When $b = 1$ and $q = 0$, the case becomes that of the ideal engine working the fluid in a non-conducting cylinder, and these equations become, for efficiency of capital and of engine,

$$r^{-n} - \left\{\begin{matrix} M \\ \text{or} \\ N \end{matrix}\right\} \frac{n - n\,r^{1-n}}{n-1} = \frac{p_b}{p_1} \qquad \text{(D)}$$

$$r^{-n} = \frac{p_b}{p_1} \qquad \text{(E)}$$

Studying these equations, it will be seen that, in all except the last (E), it is possible to find finite values of r such that their left-hand members shall reduce to zero; as in them n is nearly always equal to unity; q varies from $q = 0$ to $q = -0{\cdot}3$ in good practice, and b usually ranges between $b = 0{\cdot}8$ and $b = 0{\cdot}9$; M or N is usually between $0{\cdot}02$ and $0{\cdot}15$, and the form of the function is such that the first member may always be made to disappear for some finite value of r. Then we shall have in (B)

$$r^q + \frac{q\,r^{q-1}}{M(q-1)} - \frac{(q-n)r^{q-n+1}}{n(q-1)} - \frac{q-n+1)}{M\,n\,(q-1)} = o; \qquad \text{(F)}$$

and in (C)

$$r^{-n} - M\frac{n - n\,r^{1-n}}{n-1} = o \qquad \text{(G)}$$

$\frac{p_b}{p_1} = o$; $\frac{p_1}{p_b} = \infty$ and the value of r, at which this condition is obtained, constitutes an "absolute limit," for the care taken, beyond which expansion cannot be carried economically, even with steam increased to

infinite tension; beyond this point $\frac{p_b}{p_1}$ becomes negative, indicating the assumption of impossible conditions.

This is most plainly exhibited by equation (D). When the value of r is unity the second term disappears, as r increases; the magnitude of the whole term increases ($n > 1$), and passing through the value obtained from (F), the sign of the first member changes at some finite value of r, indicating, as above stated, the introduction of impossible conditions, since the sign of the second member must always be positive for any actual engine.

Examining equation (E), we find no such limit; the sign of the first member remains positive for all values of r, and can never become zero for a finite value of that quantity. We are thus taught that an important difference exists between the *ideal* engine, with its non-conducting cylinder, and the *real* engine working steam in a metallic cylinder, as well as between the case of maximum efficiency of engine and that of maximum efficiency of capital. In the cases of maximum efficiency of fluid and of engine for the ideal perfect engine, equation (E) only, is it true that indefinite increase of steam pressure permits indefinitely increased expansion. In all other cases an absolute limit exists, fixed for each case, beyond which expansion cannot be economically carried.

The above equations for real engines are approximate, and are practically exact—the values of the constants being determined with accuracy—within the range met with in practice, and the conclusions here deduced are, therefore, correct, although the exact values of the constants, or even the precise form of the variable function, r^q, here may not be fully ascertained.

Should it seem desirable, it is easy to deduce the same conclusions—and thus to confirm, by independent proof, the above proposition—by the examination of the "Curves of Efficiency" of ideal and of real engines. Thus:

Let the curve *ABO* be the "Curve of Efficiency" for the ideal perfect engine; let the curves *CH, DG, EF* be those obtained from real engines as indicated by the writers in earlier papers. Then if the ratio $\frac{p_b}{p_1} = o$ and $\frac{p_1}{p_b} = \infty$ the back pressure line coincides with base-line

* With such curves the ordinates measure the work done at various ratios of expansion in any given engine, by quantities of steam proportional to the abscissas.

passing through OX. Using this diagram to determine the ratio of expansion at maximum efficiency of engine, we draw the tangents OP, OK, OL, OM, to the several curves, and thus determine points of tangency—N, M, to the several curves for real engines, which, under the assumed conditions, correspond to the best ratios of expansion, the ratio of work done to cost of doing it being then a maximum.

The tangent point for the *ideal* engine, of which AB is the curve, falls at O, the origin.

Thus it is seen that, while the ratio has no limit for the ideal case, it has such a limit for the real engine, and that this limit may be found at a low ratio of expansion. The writer has made this comparison for the steamers "Michigan," "Georgiana," and "Bache," for which three cases the real curves have been obtained by him,* and finds that, these curves remaining unchanged,† it is impossible economically to increase the ratio of expansion in such engines beyond three, five, and ten respectively, even with unlimited steam pressure; *i. e.*, even when $\frac{p_0}{p_1} = 0$.‡

Such a limit must evidently exist in every steam engine, since the real curve of efficiency must fall within the ideal curve, AB, and can never pass without inflection through the origin O. The proposed proof is therefore complete, both as a matter of theory and as the fruit of direct experiment. The fact proven is due to the invariable increase of cylinder condensation with increasing expansion.

It is easily seen that a similar limit exists at still lower values for the ratios of expansion at maximum commercial efficiency, and that this holds true in all engines, the ideal case, AB, included; for, in the figure take the distance OO^1 proportional to annual "cost of engine," on the scale on which OX measures the "annual cost of steam" used in the same engine without expansion, and including in these items

* *Vide Transactions of the American Society of Mechanical Engineers*, 1882; JOURNAL OF THE FRANKLIN INSTITUTE, June, 1882.

† The form and location of these curves at very high pressures would undoubtedly be somewhat altered, but it is evident that there must still be found this absolute limit so long as condensation increases with extended expansion. The writer is inclined to believe that the form of the curves will be substantially as shown, however, at any attainable pressure.

‡ The "Michigan" has an unjacketed condensing engine, using saturated steam the "Georgiana" a similar class of engine, with superheated steam; the "Bache's"; engine is jacketed and compound.

all quantities variable proportionally with each explained by the writer in earlier papers. Then tangents drawn from O^1 to the several curves as O^1P^1, O^1K^1, O^1N^1, and O^1M^1, will determine points of tangency $P,^1K^1$, $N,^1M_1$, which correspond with such expenditures of steam and such ratios of expansion as will give maximum economy of money and minimum annual expense. It is seen by inspection of the diagram that for every case a finite value of the ratio may be obtained even at the limit at which the value of $\frac{p_1}{p_b} = \infty$ and that with any engine, however perfect, there exist values of the ratios of expansion at maximum efficiency of capital, beyond which it will not pay to carry the point of cut-off, however great the steam pressure; an infinite pressure permits only a finite expansion.

We may therefore conclude:

(1) That in all engines there exists an "absolute limit to the economical expansion of steam," whether considered with reference to efficiency of fluid, of engine, or of capital, which limit can not be passed, whatever pressure of steam may be carried up to the point of cut-off.

(2) That this limit is found at higher ratios of expansion as the type of engine is more efficient, but that the limit is indefinitely removed only in the ideal engine, and then only as affecting the ratios of expansion at maximum efficiency of fluid and engine.

(3) That this limit is found at a small value of the rates of expansion in ordinary engines, and therefore may be readily passed in every-day practice.

The limit is not far from three in the common unjacketed condensing engine, four or five in the same engine using superheated steam, and ten or twelve in the ordinary compound engine.

(4) It is evident that the general propositions of this paper are true of all heat engines having fluid working substances, whether vapors or gases worked in metallic cylinders.

Hoboken, N. J., March, 1882.

OBSERVATIONS WITH THE PLATINUM-WATER PYROMETER, WITH HEAT-CARRIERS OF PLATINUM, AND OF IRON ENCASED WITH PLATINUM.

By J. C. HOADLEY.

The observations given in detail in the subjoined table indicate that the several values assigned to the specific heat of both platinum and iron, in the tables given in my paper read before the A. S. M. E. at the Philadelphia meeting, and published in the JOURNAL OF THE FRANKLIN INSTITUTE for August, are, at the least, pretty nearly consistent with each other. The platinum heat-carrier used was: (1) 1 ball, 1·1385 in. diameter, weighing 4200 grains, = 0·6 lb. avoirdudupois, and having, at the assumed specific heat of $0{\cdot}03\dot{3}\dot{3}$ (= $\frac{1}{3}$ of the specific heat of of water) a calorific capacity equal to $\frac{1}{100}$ of that of 2 lbs. of cold water; or

(2) 2 platinum balls, one 0·9945 in. diameter, weighing 2800 grains, =0·4 lb. and an assumed capacity equal to $\frac{1}{150}$ of that of 2 lbs. of water; the other 0·7894 in. diameter, weighing 1400 grains, = 0·2 lb. and having an assumed heat capacity equal to $\frac{1}{300}$ of that of 2 lbs. of cold water. The two smaller balls together were, therefore, equal to the larger one alone.

The platinum and iron heat-carriers were two balls, alike, about 0·98 in. diameter outside, having a core of wrought iron weighing 700 grains encased in a solid capsule of platinum also weighing 700 grains. Of each metal there is, therefore, 0·1 lb. At the assumed specific heat of $\frac{1}{30}$ for Pt and $\frac{1}{6}$ for Fe, the heat capacity of the latter is five times as great as that of the former, and the combined heat capacity is equal to that of 0·6 lb. of platinum, and to $\frac{1}{100}$ of 2 lbs. of cold water.

By means of a table constructed on the same plan as the one in my paper above referred to, and to be used in the same manner, suitable corrections may be made for observations with these composite Pt and Fe balls as readily as for platinum alone.

It further appears that in the absence of platinum, or of iron balls coated with that metal, a lump of iron may be used, by the application of the proper specific heat at the observed temperature, and will give a

Table 1.

Pyrometric Observations in the Furnace of a Steam Boiler, by the Platinum-Water Pyrometer, with heat-carriers of platinum, and of iron (700 grains), covered with platinum (700 grains). Water, 2 lbs. + for heat capacity of the cup, 0·1053 lbs. = 2·1053 lbs. Assumed ratio, 105·265 to 1. Assumed specific heat, Pt = $\frac{1}{35}$, Fe = $\frac{1}{8}$ of H_2O.

No.	Observed temperatures of water in pyrometer, deg. F.	British thermal units contained in water at observed temperatures.	Heat-carrier.		Observed loss of heat by heat-carrier in cooling, deg. F.	Corrected loss of temperature, and true temp. of heat-carrier.
			Kind of metal.	Ratio of water to heat carrier.		
1	96·65	96·71195	Pt	105·265	1628·9	1487·6
	81·20	81·23740				96·7
	15·45	15·47455				1584·3
2	99·3	99·3779	Pt	105·265	1677·3	1526·7
	83·4	83·4438				99·3
	15·9	15·9341				1626·0
3	102·51	102·59753	Pt and Fe	105·265	1805·5	1496·8
	85·40	85·44580				102·5
	17·11	17·15173				1599·3
4	103·02	103·10906	Pt and Fe	105·265	1779·2	1483·1
	86·16	86·20732				103·0
	16·86	16·90174				1586·1
5	110·30	110·41098	Pt	105·265	3035·1	2546·0
	81·54	81·57808				110·3
	28·76	28·83282				2656·3
6						
	113·	113·121	Pt	107·7	3446·4	2822·4
	81·	81·037				113·0
	32·	32·084				2935·4

Note.—In Obs. 6 the platinum balls were partially fused, and 1017 grains ran off and cooled in drops like shot, sometimes several drops congealed together. One drop, weighing 95 grains, adhered to the exterior of the cup, and did not enter the water. This circumstance raised the ratio from 105·265 to 1, to 107·7 to 1.

The mean of Obs. 1 and 2 is $\frac{1584·3 + 1626·0}{2} = 1605·2°$

The mean of Obs. 3 and 4 is $\frac{1599·3 + 1596·1}{2} = 1592·7°$

The mean of Obs. 1, 2, 3 and 4 is $\frac{1605·2 + 1592·7}{2} = 1599.°$

TABLE 2.

True temperatures in degrees Fahr. corresponding with observed temperatures in columns 2, 5 and 8.	Observed loss of temperature by platinum heat-carrier at assumed ratio of specific heat H_2O to Pt as 30 to 1.	Differences of loss for each 100 degrees.		Observed loss of temperature by iron heat-carrier at assumed ratio of specific heat H_2O to Pt as 6 to 1.	Differences of loss for each 100 degrees.		Observed loss of temperature by Pt and Fe heat-carrier at assumed ratios of specific heat Pt $\frac{1}{30}$, Fe $\frac{1}{6}$.	Differences of loss for each 100 degrees.	
		First difference.	Second difference.		First difference.	Second difference.		First difference.	Second difference.
1	2	3	4	5	6	7	8	9	10
0	0·			0·			0·		
32	30·8	96·9		20·5	65·5		22·2	70·7	
100	96·9		1·7	65·5		4·5	70·7		4·1
		98·6			70·0			74·8	
200	195·5		1·9	135·5		5·3	145·5		4·7
212	207·5	100·5		144·2	75·3		154·8	79·5	
300	296·0		1·8	210·8		6·3	225·0		5·6
		102·3			81·6			85·1	
400	398·3		1·8	292·4		7·1	310·1		6·1
446·2	446·2	104·1			88·7			91·2	
500	502·4		1·9	381·1		7·8	401·3		6·9
		106·0			96·5			98·1	
600	608·4		1·8	477·6		8·9	499·4		7·7
		107·8			105·4			105·8	
700	716·2		1·8	583·0		9·6	605·2		8·3
		109·6			115·0			114·1	
800	825·8		1·8	698·0		10·6	719·3		9·1
		111·4			125·6			123·2	
900	937·2		1·8	823·6		11·2	842·5		9·7
		113·2			136·8			132·9	
1000	1050·4		1·9	960·4		12·3	975·4		10·5
1060	1119·5	115·1		1048·4	149·1		1060·2	143·4	
1082·5	1145·9			1082·5		13·1	1093·1		11·3
1100	1165·5		1·8	1109·5			1118·8		
		116·9			162·2			154·7	
1200	1282·4		1·8	1271·7		13·9	1273·5		11·8
		118·7			176·1			166·5	
1300	1401·1		1·9	1447·8		14·8	1440·0		12·7
		120·6			190·9			179·2	
1400	1521·7		1·8	1638·7		15·6	1619·2		13·3
		122·4			206·5			192·5	
1560	1644·1		1·9	1845·2		16·5	1811·7		14·0
		124·3			223·0			206·5	
1600	1768·4		1·8	2068·2		17·4	2018·2		14·9
		126·1			240.4			221·4	
1700	1894·5		1·8	2308·6		18·2	2239·6		15·4
		127·9			258·6			236·8	
1800	2022·4		1·8	2567·2		19·1	2476·4		16·2
		129·7			277·7			253·0	
1900	2152·1		2·0	2844·9		19·9	2729·4		17·0
		131·7			297·6			270·0	
2000	2283·8			3142·5			2999·4		

reasonable approximation to accuracy. Very delicate thermometers are necessary to accuracy, where 1° represents 100°.

Careful weighing of the iron, both before and after use, would be required to detect loss by oxidation. The nearer the spherical form the better, as the loss would be at the surface. At best, the results with any other metal than platinum can be only roughly approximate, and can be carried only up to about 1200°F.; and even with platinum itself there must be a margin of uncertainty—at present. For convenience of using platinum and iron, or simple iron heat-carriers, I give, in Table, 2 the corrections for platinum, for iron, and for the two metals combined in equal weights as above explained, computed in the manner already described, and to be used as indicated in this communication. By means of the columns of differences (the 1st differences alone need be used) the table will be found of easy application.

ERRATA.—The author regrets that in consequence of a necessarily hasty correction of a galley proof, without opportunity for revision, some errors in his article on the Specific Heat of Platinum in the issue of this journal for August escaped his notice. These are corrected in the following errata.

P. 92, l. 15, for $h_t = t(a + bt + ct. \ldots .)$, read $h_t = t(a + bt + ct^2 + \ldots$ etc.).

P. 95, tables, transpose the Means for 800° and 1000°, *i. e.* for ·03758, read ·03645; for ·03645, read ·03758.

P. 96, l. 16, for 0.3$\dot{3}\dot{3}$, read .0$\dot{3}\dot{3}\dot{3}$; l. 22, for .00003728, read .00009728; bottom line, for k_v, read k_t.

P. 97, first line of tables, col. 6, for —1·3, read ·0; col. 7, for 98·2, read 96·9; next to last line, col. 6, for 184·5, read 1894·5; col. 7, for 127·8, read 127·9.

PP. 97, 98, heading of col. 6, for Observed temperatures by pyrometer at assumed ratio: w. to pt. ball 100 to 1, read "Observed loss of temperature by platinum at assumed ratio of sp. ht. 30 to 1."

Note.—From the observed loss of temperature in column 6, find the corresponding *true* loss, in column 1, and to this add the temperature of the water in pyrometer after the immersion of the platinum, to obtain the true temperature of the platinam at immersion.

THE MICROSCOPE IN ENGINEERING WORK.

By Robert Grimshaw.

[A paper read at the Stated Meeting of the Franklin Institute, June 21, 1882.]

The specimens shown are intended to outline a method of using the microscope as an aid to the testing machine in estimating the value of structural materials.

While it is not intended to suggest that the microscope will determine definitely the elastic limit, nor even the breaking strain of structural materials, it is designed to convey very distinctly the idea that the microscope may be used for preliminary investigations which will determine whether or not the material is good enough to warrant its being tried on the testing machine. If the microscope condemns the material, it is not worth while going to the expense of having it tested by more expensive methods. If the microscope fail to reveal any flaw, then the material may be sent to the testing machine to be further proved. The larger the specimens that would be required for testing in the machine, the more marked the advantages of the microscope in saving, in the case of specimens readily determined to be bad, the expense of further testing, and the risk of using it in construction. The samples shown this evening are of bridge timbers, and the lesson they are intended to convey is that had this method of examination been followed, the material which was proved to be faulty after being built into the bridge, would have been promptly thrown out.

The samples shown were photographed by Mr. W. E. Partridge of New York, a professional engineer who is an enthusiastic amateur photographer, and to whom I am indebted for the particulars concerning them.

"The timber from which the poor specimens were taken came in the form of a chip broken off when a highway bridge was wrecked in 1879–80. The timber formed a portion of the sill of a draw-bridge, which consisted of two twelve-inch sticks, lying one on the other. The turn-table casting having been somewhat too small, this twenty-four-inch timber had to support one of the A frames of the bridge at a distance of twelve inches outside of the bed-plate. After a few days of service, while an empty truck was passing over, the strain became so

great that the A frame sheared the twenty-four inch sill, wrecking the whole bridge. The timber was so exceedingly poor that upon mounting it on the microscope the porous and weak nature of its structure was at once discovered. Its annular rings are something like three times the distance apart which would be found in a piece of thoroughly good wood of a similar character. The medullary rays are few in number and short in length, while in good wood they are of considerable length, and so numerous that the tangential sections appear like a series of tubes seen endwise or a number of parallel chains. After once seeing and comparing two samples of wood it is very easy to recognize their characteristic features by the use of a pocket magnifying glass."

The trunks and limbs of exogenous trees are built up of concentric rings or layers of woody fibre, which are held together by radial plates acting like the trenails of a wooden vessel, or the "bonds" in a brick or stone wall. The rings or layers, representing successive years' growths, are composed of tubes, the interstices between which are also filled with cellulose. The slower the growth of a tree, the thinner these yearly layers, and the denser and harder the wood,—other things being equal. This is true as between one kind of tree and another, and also as between different individuals of the same kind.

Not only is the closeness of the growth an indication of the hardness and strength of the timber, but the size, frequency, and regularity of distribution of the radial plates which bind the layers together may be taken as a very close illustration or sign of the character of the wood and its ability to resist strain, especially that from crushing stress.

The micro-photographs of the sections of good and bad timber show that in the strong specimens the concentric rings are close in texture and of slight width; and the radial plates frequent, wide, long, and thick, while in the poor material, the reverse characteristics are shown.

The lesson to be learned from these micro-photographs is that having proper views of transverse and radial lengthwise sections, and of sections perpendicular to a radius, of a standard piece of timber resisting certain standard or minimum strains,—all timber having fewer rings per inch of tree diameter, fewer fibres, and fewer and shorter radial plates per square inch of section, should be rejected as not up to the standard, and applied for other purposes or used with a greater factor of safety.

This method has the advantage of enabling every stick of timber in a bridge to be inspected and judged, and is offered as an interesting and valuable aid to the breaking tests made by the machine.

In this connection, I may offer as the parallel in metal work two portions of pure Lake copper; one an ingot as ordinarily found, in which the grain is coarse and crystalline, the color dark-red, and the mass full of blow-holes; this is an average sample of copper casting. The other is run from the same pig, at the same heat, and in a similar mould, but with proper precautions to prevent oxidization; in consequence, there are no blow-holes, the grain is close and fine like that of the best bronzes, and the color is *salmon*, which is the true copper color. The "deoxidized" casting weighs 25 per cent. more than the ordinary casting from the same pattern, calipering the same. For these I am indebted to the Philadelphia Smelting works, Twelfth and Noble sts.

Tests made of the deoxidized copper rolled into sheets ·035 inch thick showed on strips 2 inches wide a tensile strength of 33,760 pounds per square inch, ordinary fine copper in sheets being quoted by Trautwine at 30,000 pounds. This would show 12·5 per cent. superiority in the metal having the fine fracture.

No. 20 "deoxidized" wire shows a calculated tensile strength of 45,000 pounds per square inch, and still later tests of wire of the same thickness showed a calculated tensile strength of 41,056 pounds per square inch for the ordinary, and 47,552 pounds for the deoxidized,* a striking confirmation of the indications of the microscope.

Transmission of Force to Great Distances.—Emile Lacoine shows that the distance to which a dynamo machine can transmit any given fraction of its energy is inversely proportional to the square of the section of the enrolled wire, and the temperature of the conductor is raised much less in proportion as the distance increases.—*L'Electricien.* C.

* Actual breaking strength of the wires, 39½ and 39½ pounds for two samples of the "commercial," and 44½ and 47 pounds for the "deoxidized." It must be remembered that the larger the specimens tested the lower the tensile strength per square inch of section, and the finer the wire is drawn the greater its tensile strength per square inch, and the less the superiority of the metal which was close-grained in the ingot.

TESTS OF DOUBLE RAW HIDE BELTS.

By JOHN E. HILLEARY.

[A paper read at the Stated Meeting of the Franklin Institute, May 17, 1882.]

Having made some tests of new riveted double so-called "raw hide" (semi-tanned and fulled) belts on a 36-inch new wooden pulley, with 180° are of contact and tensions of 25 and 50 pounds per inch of belt width, I find them as follows:

With the grain side next the pulley (both grain sides were out, as is usual with tanned leather belts) the grip with 25 pounds tension per inch was 200 pounds, and with 50 pounds, 460 pounds. It thus seems that in the case of this 4-inch new double-fulled leather belt, on that new 36-inch wooden pulley, with 180° arc of contact, doubling the tension more than doubled the grip, the latter being as 100 to 230.

Comparing the grip of the double belt with that of a single belt of the same material, under the same conditions (grain side to), we find as follows:

	Single.	Double.	Ratio showing influence of thickness.
25 pounds tension per inch . .	300	200	0·66⅔
50 " " .	400	460	1·15
Ratio showing influence of tension.....	1·33	2·30	....

These results are curious, and would indicate, without looking into the matter, that with new riveted double "fulled" belts on 36-inch new wooden pulleys, with 180° contact and tensions of 25 and 50 pounds per inch width—

(1) With light tensions a double belt will not grip as well as a single one.

(2) With heavy tensions a double belt will drive more than a single one.

(3) Both single and double belts drive better with heavy than with light tensions.

(4) The influence of tension is more marked with double than with single belts.

In reference to "raw hide" belts there are some that get hard after running a while, while others remain pliable and elastic. By "elastic" I do not mean that they stretch so as to necessitate being taking up constantly; for a belt that needs taking up every little while is not elastic. If it were elastic, the local extension in length while in contact with the pulley would be counteracted in each portion as soon as it got round to slack side.

I want to be particularly understood as repudiating, as yet, any general formulæ or statements covering the working of belts on pulleys where all the conditions are not stated. Some of my notes may seem to contain needless repetitions, but they are cautionary limitations. If, after making my tests of new single leather belts on new cast-iron pulleys, I had formulated the rule that new leather belts drive best flesh side to the pulley, I should have been badly "out" on the subject of semi-tanned leather belts.

New Determination of Joule's Equivalent.—Cantoni and Gerosa have determined the mechanical equivalent of heat by a series of experiments in which they substituted mercury for water. Its great thermal conductibility, and the relative invariability of its specific heat at the low temperatures which they employed, induced them to make the substitution. The method of experimenting consisted in the sudden arrest of a mass of mercury, falling from a given height and consequently provided with a known amount of dynamic energy. The increase of temperature at each experiment was carefully measured, and the dynamic equivalent of caloric deduced by a simple calculation. The mean of all the results is almost precisely the same as that which Joule obtained from his most satisfactory experiments. The agreement of the values which are furnished by two processes that are so distinct seems to give complete assurance of the accuracy of the results. C.

GREATEST RINGING BELLS.

By JOHN W. NYSTROM.

Russia is famous for having the greatest bells in the world, but if the great *Tzar Kolokol* of Moscow, which has never served the purpose of a bell, be excluded, then Burmah takes the honor of having the largest ringing bells.

BURMAH BELLS.

The Burmah bell founders appear to have attained great perfection in that art, and they take great pride in their productions. The quality of tone of the Burmah bells are said to be very fine. The Mengoon bell is the greatest ringing bell in the world, weighing 201,600 pounds, and its probable diameter is 203 inches.

The great bell in Rangoon, called "*Maha Ganda*," weighs 95,000 pounds, with probable diameter of 155 inches, is said to have a very fine tone.

RUSSIAN BELLS.

The first great bell in Moscow was presented to St. Ivan's Church by the Tzar Boris Godunof, in the sixteenth century. This bell was actually hung and rung, but its weight, 288,000 pounds, was too great for its support, it fell and broke and was recast in the year 1654. Diameter, 216 inches, and soundbow 18 inches. During the fire in 1706 the bell fell and broke again.

The greatest bell in the world is that at Moscow, called *Tzar Kolokol*, or monarch bell. Its dimensions are 19 feet 3 inches high, diameter 22 feet 8 inches, thickness of soundbow nearly 2 feet, and weighs 443,772 pounds. The weight has evidently been calculated, because the Russians had no scale upon which it could be weighed. From the dimensions of the bell, taken by the writer and the weight calculated, it should weigh nearly 500,000 pounds.

According to inscription on the bell, it was cast in the year 1733. In those days they had no means of transporting heavy weights and great bells were, therefore, cast in the churchyards close to where the bell was to be hung, as was the case with the great Moscow bell, which was cast in a pit close to St. Ivan's Church, in which tower it was intended to be hung.

The moulding of the bell was probably done in the ordinary way, namely, the core was built first, upon which the thickness of metal was laid with loam or clay, and the cope built over it. Judging from the unevenness of the inside surface of the bell, it is probable that the core was not swept but dubbed up, so that the bell is not of even thickness at equal distances from the lip. The outside surface is very even, and has evidently been swept by a steady sweep.

In preparing and melting the metal for casting the bell it appears that no exact composition was attempted, for the nobles and other capitalists of Moscow threw a great amount of silver and other metal into the furnace, which made it an uncertain alloy with much greater shrinkage than the minimum, which is, with 31 parts of tin to 100 of copper.

The moulding, casting and precautions for cooling and shrinkage of a bell of this size require more practical experience than probably these bellfounders were in possession of, for it is evident that the bell broke by shrinkage in the pit in which it was cast.

The cooling of a bell of this size requires a time of at least one month if not six weeks, from the day it was cast, but it appears that the bell founders attempted to dig up the bell a few days or a week after it was cast; and it is also said that water was poured on the mould or casting; at all events, the bell was cooled too quickly and cracked in several places around the lip, and in one place a piece weighing about 11 tons was broken off. The uneven thickness of metal also aided the breaking.

The great Moscow bell has, therefore, never been sounded, but laid in its casting-pit, partly uncovered, for a time of 103 years, in which time it was held in reverence by the natives who were extremely jealous of its being touched or measured by strangers. Thus it laid as an object of wonder to travelers, and the people of Moscow visited it with pride at their festivals.

In the year 1836 the Emperor Nicholas decided to have the bell exhumed and raised, which was accomplished with great difficulty and expense. The engineers who first undertook to raise the bell were not given a fair chance to accomplish the work, because on their first trial the tackle were too light and gave way, for which the engineers, it is said were sent to the mines of Siberia.

The board of admiralty then undertook to raise the bell, and succeeded in placing it in the position as shown in the accompanying illustration, which is reduced from a large photograph procured by the writer in

Moscow, in the year 1871. The bell is placed south of St. Ivan's Church, on an open plazza in the Kremlin, near to where it was cast.

It is said that the Empress Anne presented the bell to the church, but however that may be, it is known that the fragments of the bell which fell and broke in 1706 were used; and the citizens of Moscow contributed largely to the metal in the bell which contains much silver and some gold. It is said that the value of the metal in the bell is $332,000, all uncirculating and dead money, for the bell has never struck a note.

"Think of that, ye money-mongers on the Rialto," says Rev. Alfred Gatty.

In some records of the great Moscow bell it is stated that the bell was actually hung and rung in the tower of St. Ivan's Church, and that it had been broken by falling to the ground. It is also stated that the building over the casting pit took fire after the bell was cast, and the water used for putting out the fire fell on the bell in the pit and caused its breaking. But these records have been contradicted by competent judges.

Tzar Kolokol.—Description of the Plate.

The accompanying plate, representing the "Bolshoy Tzar Kolokol," is produced by the phototype process invented by Mr. C. H. Jacobi, of Neuendorf-Coblentz, and now used exclusively by Mr. F. Gutekunst, 712 Arch street, Philadelphia. This process (with others allied to it) is one of the great achievements of recent times. With its aid a view can be taken from nature and as many copies as desired may be reproduced in the printing-press, preserving the softness of a photograph, the permanency of a steel-engraving and the absolutely correct representation of the original object. The illustration has never been touched by any handwork or artistic skill, but a negative taken from my photograph by which the printing-plate was prepared. This process is well known and widely used in Germany, and will, no doubt, be so also in America, for it has fortunately fallen into good hands.

The great Moscow bell, as represented on the plate, rests on a granite pedestal with its broken off piece on the ground. The enormous size of the bell can be perceived by the proportionate size of the men standing at the foot of it and by the size of the cathedral behind. The St. Ivan's

Phototype. F. Gutekunst. Philada.

GREAT BELL OF MOSCOW.

FOUNDED 1733.

Height 21 ft. 4½ in. Diameter 22 ft. 8 in. Weight 198 tons.

Church, in which tower the other large bells hang, is close by to the right of Tzar Kolokol, but not shown on the plate.

The scale of the bell represented on the plate is 8·095 feet to the inch, in the plan passing through the axis of of the bell and parallel with the plate; but that scale will not be correct for measuring the height of the men in front of the bell, because they were 13 to 14 feet nearer to the camera obscura when the photograph was taken, and they therefore appear larger by that scale. The same is the case with the broken off piece on the ground, which by scale measurement is larger than the hole in the bell from which the piece was broken. The church on the other side of the bell is larger than the scale measurement. The axis of the photographic instrument was placed level with the lip of the bell.

The female figure in base relief on the left side of the *latus* represents the Virgin, and the inscription is on the right side towards St. Ivan's Church. The uneven thickness of metal, at equal distances from the lip, can be seen and measured at the top of the broken off piece on the ground. The form of the bell and its base relief ornaments are master pieces of fine arts. Omitting the accidental unevenness of thickness, the proportions of the bell indicate that its constructor understood the acoustic properties of the vibrating metal when a bell is tolled.

Our modern celebrated bell founders are far behind that constructor in proportioning bells for quality of sound. I should like very much to see the Tzar Kolokol recast the same size, and the form and ornaments exactly preserved. With our present knowledge and experience in founding the recast bell would be a success.

The other great bells in Moscow and other places are noted in the accompanying table, in their order of sizes.

The Russians have generally a great number of bells of different sizes in their churches, but they are not toned for musical harmony or melody, and their ringing is not agreeable to strangers, who often make severe remarks upon their noise. During my five years in Russia I could never get accustomed to or appreciate the bell-ringing, which is a disagreeable jangling.

The great bell in St. Ivan's Church is rung three times a year, and produces a tremulous effect throughout the city, like a distant thunder or the low notes on a powerful organ.

The old bells of Russia are much better in tone than modern bells cast in Moscow 25 years ago or thereabout, but I have information that they make better bells now.

The Russians never swing their bells, but hang them stationary, and even the smallest church bells are rung by ropes attached to the clappers.

Chinese Bells.

China is next in order of great bells, but their awkward form and projecting ornaments make them far inferior in tone to our bells.

The great bell in Pekin weighs 120,000 pounds, diameter 13 feet, and height 14 feet 6 inches. It is rung by one man striking its outside by a wooden mallet. An ordinary iron clapper would probably break the bell on account of its irregular distribution of metal.

The great bell of Nankin weighs 45,000 pounds. Large bells are very common in all cities of China, but all bad in tone, and chime ringing is unknown there. The construction of China bells shows absolute ignorance of the science of acoustics as applied to that art.

Japanese Bells.

In Japan, ringing bells are very common, and are a little better than those in China. They make the bells cylindrical, with a spherical top, and ring them by a weight hung on a rope striking the bell outside.

The Chinese and Japanese bells require double the amount of metal for the same volume of sound produced by our bells.

The ancient literature, that is, from the year 1495 to the end of the last century, was rich on bells, and the subject was treated by able scientific men. A civil judge, Maginus Tintunatius, in the Venetian service at Candia, when besieged by the Turks in the year 1571, was taken prisoner, and in his captivity amused himself by writing a treatise on bells, which is said to be the best written on that subject; but, as the Turks considered the bell as a symbol of sinful infidelity, the author was beheaded by the order of a pasha. The manuscript was, however, preserved and published, by which his name is immortal.

When the Turks took Constantinople, in 1453, they forbade the ringing of bells, for the purpose of preventing signals being given for popular revolt.

The art of bell founding has not advanced in this century, but has gone backwards in many cases, which proves conclusively that a good bell cannot be produced by practical experience alone, but a scientific knowledge of acoustics is necessary with experience, not only for making a good bell, but also for producing the maximum volume of sound with the minimum quantity of metal.

The Largest Ringing Bells in the World.

NAMES AND LOCATION OF BELLS	Date Cast.	Actual Vibrat	Key-note.	Diam. Inches	Soundbow. Inches	Soundbow. Stroke.	Weight Pounds
Moscow, Tzar Kolokol	1733	74	D	272	23	0·84	443,772
Burmah, Mengoon	.....	94	F♯	203?	16?	0·80	201,600
Moscow, St. Ivans	1819	105	G♯	185	14·75	0·80	127,350
Pekin, Great Bell	.....	.....	.....	156	.....	.....	120,000
Burmah, Maha Ganda	.....	125	B	155	12·5	0·80	95,000
Nishni, Novgorod	.....	125	B	151	12	0·80	69,664
Moscow, Church Redeemer	1879	141	C♯	136·3?	10·6	0·80	60,736
Nankin, China	....	.....	.....	112	.....	.....	45,000
London, St. Pauls	1881	157	E♭	114·25	8·75	0.76	42,000
Olmutz, Bohemia	.....	157	E♭	121	9·125	0·75	40,320
Vienna, Austria	1711	157	E♭	118	9·5	0·80	40,200
Westminster, London	1856	166	E	113·5	9·375	0·83	35,620
Erfurt, Saxony	1487	176	F	103·6	9·75	0·75	30,800
Notre Dame, Paris	1680	166	E	103	7·5	0·73	28,670
Montreal, Canada	1847	176	F	103	7·8	0·76	28,560
York, England	1845	187	F♯	100	8	0·80	24,080
St. Peter, Rome	1786	187	F♯	97·25	7·5	0·77	18,000
Great Tom, Oxford	1680	210	G♯	84	6·125	0·73	17,024
Cologne, Germany	1477	198	G	95	7·2	0·76	16,016
Brussels, Belgium	.....	210	G♯	95·81	7·75	0·71	15,848
State House, Philadelphia	1875	198	G	88	6·375	0 73	13,000
Lincoln, England	1834	210	G♯	82·85	6	0·73	12,096
St. Paul's, London	1716	222	A	81	6·08	0·75	11,500
Exeter, England	1675	210	G♯	76	5	0·66	10,080
Old Lincoln, England	1610	249	B	75·5	5·94	0·78	9,856
Westminster, London	1857	249	B	72	5·75	0·79	8,960

Liberty Bell.

The Liberty Bell of Philadelphia was cast over four times before it became qualified to ring-in the Independence of the United States of America. It was cast the first time by Lester & Pack, 267 Whitechapel, London, in the year 1752; brought to Philadelphia and hung in the State House the same year, but when struck for the first time it gave a droll sound, and upon examination it was found to be cracked in the rim. It was then decided to send the bell back to London and have it recast in the same foundry, but Messrs. Pass & Stow, brass founders, undertook to recast the bell in Philadelphia. The first recast bell, in 1753, did not satisfy the authorities, and a second bell was cast from the same original metal, but without the anticipated success, but it was broken up and recast a third time, when it proved successful, and twenty-three years after it rung-in this nation's independence of a foreign potentate. Its weight is 2080 pounds. In the morning of July 8, 1835, it was cracked while being tolled in memory of Chief Justice Marshall, but was still rung, with a doleful sound, until the 22d of February, 1843, when the crack increased so as to make the Liberty Bell thenceforth mute forever, though not dead. It was placed on the honorable retired list, and hung in a conspicuous place in the Hall of Independence, on duty to pay homage to visitors.

The accompanying illustration of the Liberty Bell is of a scale 0·55 of an inch to the foot.

Diameter at the lip, . . .	48 inches.
Thickness of soundbow, . .	3¼ "
Keynote, American pitch . .	E.
Double vibrations per second, .	392.
Weight, . . .	2080 pounds.

The predestination of the Liberty Bell was inscribed with raised letters cast on it in London, 1752, as ordered by the Assembly of the Province of Pennsylvania. The same inscription was put on the recast bells by Pass & Stow, Philladelphia, 1753, namely, as follows:

"Proclaim liberty throughout the land to all the inhabitants thereof."—Levit. xxv, 10.

The predestination was realized twenty-three years after the bell was cast, when the sovereign people assembled, with the benediction, *All men are born free and independent.*

The 10th verse, chapter xxv of Leviticus reads thus: "And ye shall hallow the fiftieth year, and proclaim liberty throughout *all* the land, unto all the inhabitants thereof; it shall be a jubilee unto you." Like a flash of lightning the quotation became intelligible to every ear, and was promulgated in rhyme and prose.

Second State House Bell.

The second State House bell was cast by John Wiltbank, of Philadelphia, in the year 1828, and weighed 4600 pounds. This bell was cast over three times before proving successful, but the last one turned out to be a very good bell, and was used for fire alarm and time striking. In the year 1875 it was taken down and removed to Germantown Town Hall, where it is now doing good service by sounding time with the same old clock as used in the State House.

Third State House Bell.

The third State House bell was presented to the City of Philadelphia by Henry Seybert, Esq., on July 4, 1876. Its weight is 13,000 pounds, and was cast twice by Messrs. Menealey & Kimberly, of Troy, N. Y. The first bell, after having been hung in the State House

tower and sounded, was found to be unsatisfactory in quality of tone, whereupon it was taken down and returned to Troy for recasting. The second bell proved to be a little better, but competent judges say that it is not a good bell. Its dimensions and key-note will be found in the foregoing table. Mr. Seybert also presented to the city the clock which strikes the bell.

Westminster Bell of 1856.

The London Westminster bell of 1856 proved to be a failure, and was therefore taken down and recast the next year. The first bell weighed 35,625 pounds, and the second weighs only 8960 pounds.

There are many bells rung in different parts of the world which are much worse than some of those that have been condemned for producing bad sound.

REPORT ON EUROPEAN SEWERAGE SYSTEMS, WITH SPECIAL REFERENCE TO THE NEEDS OF THE CITY OF PHILADELPHIA.*

By Rudolph Hering, C.E.

Philadelphia, Autumn of 1881.

Samuel L. Smedley, Esq.,
Chief Engineer and Surveyor of City of Philadelphia.

Dear Sir:—In order to finally present the conclusions gained during my visit to Europe, and their application to Philadelphia, I shall group the material according to subjects, instead of to the places visited, which latter method, however, was the more expedient one to pursue for the six preliminary reports I sent you from Europe. And I shall confine myself now to the consideration of only those points which have a bearing on the existing works and future needs of our city.

The best way of treating the matter will be: To briefly state the conditions presented by our city, and allude to its present sewerage system, the details and management, in order to clearly understand in

* The author of the following report was selected by the National Board of Health to examine and report upon the sewerage works in Europe. The report we publish was prepared from facts noted and observations made while performing this duty.

what directions improvements are most desirable in the light of experience gained in other cities.

Then, it will be in place to state how the same or similar conditions have been treated elsewhere with success, referring to the general design, the details, the management and the cost, and finally to give the conclusions for our own purpose, as indicated thereby.

Before entering upon the subject I desire here to express my sincerest thanks to the gentlemen who so cordially gave me the desired information. In the many towns of England and Germany where the sewage question has received attention, as well as in Paris, Vienna and Zürich, I was met by the municipal engineers and others with the greatest courtesy, and was always cheerfully aided in my endeavor to obtain a fair knowledge of their works. And I feel under special obligations to the chief engineers and their assistants who accompanied me into or through some of their sewers, a labor sometimes not very agreeable except to those who feel the deepest interest in one of the most important branches of sanitary science.

I have attached to this report the following appendices to which occasional reference will be made.

Appendix No. 1. Area, population and dwellings of Philadelphia according to wards.

Appendix No. 2. Heaviest known rainfalls in Europe compared with Philadelphia.

Appendix No. 3. Regulations for house sewerage in Frankfort-on-the-Main, Hamburg, Berlin, Danzig and Seven-Oaks Local Board.

Appendix No. 4. Drawings of sewerage details as follows: Sections of sewers in Paris, Berlin, Vienna, Hamburg, Frankfort, Brighton and Oxford. Junctions of three sewers in Berlin and Frankfort. Overflows in Berlin, Brighton and Zürich. Manholes in Berlin, Liverpool, Frankfort and Munich. Side-entrances in Paris and Frankfort. Ventilating and flushing shafts in Frankfort and Munich. Street inlets in London, Paris, Berlin, Hamburg, Liverpool Frankfort, Brighton and Zürich. Catch-basin for debris from a sewered mountain creek in Zürich. Details for cast-iron covers for manholes, etc., egg-shaped tide-flap, foot-irons and flushing slide.

Appendix No. 5. Sewage plans of London, Paris, Berlin, Vienna, Liverpool, Hamburg, Frankfort, Oxford and Danzig.

An inquiry into the question of city sewerage discloses a marked difference of opinion regarding the best methods, and this is not simply

confined to the numerous details of the works, but even to the general systems themselves.

We find in our own country a discussion inaugurated on the propriety of leading rain-water and sewage into the same channels. One party holding that there should be two "separate" systems for this purpose, another, that there should be one, a "combined" system. A similar variance of opinion is found in England.

In Paris, the present method pursued is to lead, besides the rain-water, all ordinary house waste-water into sewers, but to exclude the excreta from four-fifths of the population, and from the remaining fifth their solid portions, which are removed in casks or by odorless excavators from cesspools, as in Philadelphia. This state, however, is not a permanent one. The municipal engineers favor complete water-carriage, and improvements in this direction are constantly made.

In Germany, the opinions are divided on the question, whether they shall remove the excreta by casks or pails, usually termed the process of "dry removal," or by sewers through "water-carriage."

Finally, there is a party advocating the so-called Liernur system, where the excreta and a certain portion of the house waste-water are led into a system of iron pipes and removed pneumatically by means of an engine at a central station. The remaining house-water is taken away with the rain-water in a separate system of brick sewers.

In examining these various systems, most of which are found to work well at certain places, and comparing the opinions given by the advocates and opponents of each, it became evident that both the advantages and disadvantages were frequently exaggerated. The true question and the one where agreement could be attained, appeared to be, not as to what method is the best *per se*, but rather, under what circumstances or external conditions each of the several good systems become the most advisable.

And herein lies, in my judgment, the solution of the general sewage question. When well designed, well built and well managed most of the systems can give satisfactory results. Yet each one will have a certain range of applicability where it has advantages over the rest, and therefore is preferable.

When wishing to adopt a system for a town, we should therefore not ask, in a general way, what system of removing offal and waste-water is the best, but, rather, which of them is most suitable to the local conditions presented by the town. And this question I shall

now endeavor to answer with reference to Philadelphia by discussing 1. What system is best applicable to Philadelphia; 2. House sewerage, 3. Street inlets or gullies; 4. Sewers; 5. Junctions, connections, overflows and outfalls; 6. Appendages to sewers for inspection, ventilation and flushing; 7. General alignment of system; 8. Management and cost; 9. Recapitulation of general conclusions.

I. What System is Best Applicable to Philadelphia?

In conformity with the method indicated, it will first be proper to review our own conditions and needs, then to examine other works under similar circumstances, and finally, to draw any conclusions that may present themselves with regard to benefiting our city.

Philadelphia lies at the confluence of the Delaware and Schuylkill rivers,* and about eighty miles above the point where the former flows into the Atlantic Ocean. The tide rises and falls six and a quarter feet, the water never becoming brackish. Near the centre of the city the Schuylkill is dammed to a height of about seven feet above ordinary high tide, the water above being used for domestic and other purposes. Four-fifths of the entire quantity of water consumed in the city is obtained from this stream, while one-fifth is taken from the Delaware River.

The pollution of our drinking water by sewers discharging into the rivers does not need examination at this place. It is only necessary to state, that the time is very near at hand, if it has not already arrived, when the indiscriminate discharge of sewage into the rivers will require some restriction or modification, and future sewerage works should be designed with this point held in view.

The density of population varies considerably in the different sections. The best idea regarding it can be obtained from the map published in the *Proceedings of the Engineers' Club*, Vol. II, No. 1, in which I plotted the density from the areas of election divisions, which are comparatively small units, and were the only available data.

The topography of the city varies from very flat and low sections in the southern and eastern parts, to undulating and high grounds, in the west, northwest and north, reaching elevations of several hundred feet. The city is growing chiefly towards the elevated portions, but commer-

* Delaware drainage area, 8,305 square miles; minimum daily discharge, 173,300,000 cubic feet. Schuylkill drainage area, 1,936 square miles; minimum daily discharge, 30,000,000 cubic feet.

cial interests tend towards gradually covering also the low country towards the mouth of the Schuylkill.

The site of the city, besides being one of the largest built up areas in the world,* is varied in its character from flat to hilly sections, is intersected by several large creeks, viz.: the Wissahickon, Pennypack and Tacony, and includes two large navigable rivers.

The subsoil consists of loam, gravel and clay, varying in depth from 0 to 60 feet, and is underlaid by gneiss-rock. Subsoil water is found only in places, and is slight in quantity, except near the river.

The climate af Philadelphia, respecting the extremes of temperature, their duration and the maximum rain and snow-falls, varies slightly from other towns in the Middle States, but more from most of the large European cities.

Our yearly maximum temperature reaches from 90° to 100°, and our minimum from 10° above to 10° below zero. Our highest temperature is reached within a few degrees, pretty generally in Europe, but the lowest is only found in Germauy, Austria and in the countries north and east of them.

The maximum rainfalls that have been registered in our city are found in Appendix No. 2, where also the European storms are tabulated. It will be noticed that the latter are substantially as heavy as our own.

Snow has fallen in Philadelphia to a depth of three feet, and has remained on the ground for several months, the depth of frost being usually from two to three feet. In England and Paris the amount of snow falling is light, as is also the depth of frost, whereas Germany and Austria closely resemble our own city in this respect.

Philadelphia is divided into numerous natural drainage areas. The water-shed line between the two rivers, beginning at Chestnut Hill, traverses Germantown and Nicetown, then passes on to Laurel Hill, from there to a point near Eleventh and Arch streets, and finally loses itself near Point Breeze. The territory towards each river is subdivided into a great number of smaller areas generally running directly to the river.

The natural surface drainage is, therefore, plainly indicated. The artificial drainage by sewers has closely followed it, excepting in a very

* Area within municipal boundary, ... 129 sq. miles.
" of built up portion of city, . . . about 20 "

few instances, such as the short intercepting sewers preventing sewage from entering the Schuylkill River immediately above the dam. In other words, the sewers have, as a rule, been built along valley lines and finally reach the rivers, at or near the points where the rain-water previously entered them.

The surface characteristics are as follows: Streets are paved with Belgian blocks, cobble and rubble stones, and sidewalks are paved with flagstones and bricks, laid on a bed of gravel or sand. Closely built-up sections, which therefore offer little chance for rain-water to soak into the ground, are confined to the older parts of the city The area adjoining them, covered principally with dwelling houses, contains a large amount of garden surface, with lawns or open soil, estimated at one-quarter of the area, on which a considerable portion of rain-water can be absorbed. Further towards the periphery are rural sections, where a still greater amount can soak into the ground. In making provision for leading away the rain-water this circumstance is of importance as determining its quantity and the size of the channels intended to remove it.

The water supply of the city is fair in quantity. It is about sixty gallons per day per head, of total population.* As pipes are laid through the streets of all built-up sections, but not in the village districts, the quantity per head of consumers is even greater.

The existing works for the removal of excreta, waste and rain-water can be briefly described as follows:

There are about 154,000 houses in the city. It is estimated, in the absence of exact statistics, that there are about 75,000 cesspools, most of which are so placed that one serves two houses. It is not far from the truth to say that 145,000 houses have cesspools attached to them. Further, as the sewers have been extended, houses have been connected with them, but the cesspools were not always obliterated, but

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* Water supply of several European cities:

Oxford, *Separate System of Sewerage*,	53 gals. per head.
Paris,	50·2 " "
Hamburg,	46·0 " "
London,	32·7 " "
Liverpool,	32·3 " "
Danzig,	32·0 " "
Berlin,	31·7 " "
Frankfort,	31·0 " "
Vienna,	16·0 " "

left for use and provided with an overflow pipe to the sewer. The number of cesspools thus retained is estimated at one-third, or 25,000. The remaining 50,000 have no connection whatever with sewers, and being lined with a brick wall, usually built without any mortar, and which is perhaps not in a single instance water-tight, allow the liquids to soak away into a stratum of gravel or loam underlying the greatest portion of the city. The serious effects which may result from this in the future are not difficult to conceive.

Records show, further, the existence of about 34,000 water-closets. Some houses have two closets, but they are few. As the average number of persons to a house is 5·5, and among the wealthier classes where the water-closets are generally in use, even less, it is plain that the sewers can regularly receive the excreta from not over 200,000 persons, or less than one-quarter of the city's population.

To this must, however, be added the overflow from cesspools which are connected with sewers. Unless they are water-tight, the overflow will not be regular. Only when a large amount of water, from kitchens or bath-rooms, is suddenly run into them, a discharge into the sewer may take place. The quantity of excreta getting into the sewer this way is impossible to estimate. An idea only may be gained by considering that about 12,000 of the houses, which are connected with the sewers, have cesspools still in use and no water-closets.

These figures indicate that our means for disposal of excreta can be estimated to be less than one-fourth by sewers or water-carriage, and more than three-fourths by cesspools, where the solids are generally stored for months and years and the fluids soak into the soil underlying the city.

House waste-water, where connections are made with sewers, is also led into them from all houses provided with water-closets, therefore from 34,000. In addition, there are about 6,000 houses where only waste water is led into the under-ground drains. And finally, there is a large amount of house-water which runs into the street-gutters and thence into sewers, which has been estimated as equivalent to the entire drainage of 10,000 houses. Therefore, the house-water reaching our sewers may be said to come from about 50,000 houses, representing one-third of the city's population.

Although these figures are rough approximations, yet they are sufficiently accurate to show, as the sewers provide for the excreta of about one-quarter and the house-water of about one-third of the popu-

lation, that water-carriage is by no means the prevailing system in our city, as frequently imagined, for removing fæcal matter and liquid filth from our dwellings. It must be added, however, that the yearly increase of water-closets and of connections made with relatively old sewers indicates an increase in their use over cesspools.

The extent of the sewerage executed up to January 1st, 1881, is as follows: Total length of sewers, of which nearly all are circular in shape, is 198·44 miles, costing $4,500,000, of which 44·61 miles are more than three feet in diameter, a few miles only being less. The number of inlets to them at street gutters is about 4500. The number of house connections is about 40,000.

In order now to determine which of the general methods for removing house filth is to be recommended for Philadelphia under the just mentioned conditions it is necessary to review the various methods at present in use and to state the condition under which each one has been found to be best applicable. As I have elsewhere* given a general account of these methods and the conclusions gained regarding their relative merits and applications, I refer to it here and shall only extract as much as concerns my present purpose.

All of the prominent systems for removing waste-water, if properly designed and built, I found to answer the sanitary demands within satisfactory limits. Water-carriage, however, is always preferable to dry methods on account of its greater cleanliness and of the quick and continuous removal of the filth.

Among the water-carriage systems themselves, there is little difference in this respect. The "combined" system, removing sewage and rain-water by the same channels, is preferable to the "separate" system for large areas of thickly populated districts, where under-ground rain-water removal is required, because it is only a single system. This circumstance reduces the number of sewers, facilitates maintenance by allowing better inspection, on account of their greater size, and by the natural flushing of periodical rain-storms. The separate system, however, is preferable to the combined whenever the rain-water can be made to run into old channels or over the surface into the streams, because the fluctuations of the sewage alone will suffer less retention of foul matter than the greater fluctuations due to the admission of rain-water.

*Paper read before the Am. Society of Civil Engineers, June 18th, 1881.

These are the conclusions mainly regarding the sanitary question, and similar ones result when considering the financial question.

A well attended system of dry removal is least expensive, as a rule, only for villages or isolated mansions.

The separate system is naturally cheapest when rain-water can safely and without annoyance flow off on the surface, which is often the case in rural districts, or when it can be turned into old sewers that are not suitable for sewage removal.

The combined system is most economical, as a rule, when storm-water must be carried away under-ground, as from extensive and closely built up districts, and when new sewers must be built for this purpose, which is the case in large or rapidly growing cities.

Local conditions may, of course, modify these points, and in many cases nothing but an examination of the topography and existing works and into the cost itself will determine the most advantageous system.

On the basis of these general conclusions, I shall now state the special conclusions, which I have reached regarding the system or systems best applicable to Philadelphia.

Water-carriage is greatly to be preferred in all districts to which water-supply and sewers can be extended without too great a cost, not only because one-third of our population is already provided for by it, but because the extent of the city, its topography as described, the two large rivers and the abundant use of water, make it the most expedient. The large area of Philadelphia would make a systematic dry-removal enormously expensive, if it is to answer all sanitary requirements. The topography and the soil offer no difficulties in the way of sewerage. The body of tidal-water is sufficient to receive the entire sewage of the city, without creating a nuisance at the wharves, if discharged only during the out-flowing tide. And if, in the distant future, it becomes necessary to purify some of the sewage, there are grounds below the city where a large amount could be used for irrigation. Finally, the abundant supply of water would alone require the use of an extensive sewerage system to remove it from the houses and streets.

The principle of water-carriage, which Philadelphia adopted many years ago in conjunction with other American cities, therefore, is the best one for our conditions.

Yet there are sections of the city where an exception should be made. In the village portions of the county, especially those which are some distance from the city, and which it will be expensive, for many years

hence, to connect with the present sewers, other methods are to be preferred until then, as a temporary expedient. The common privy is not objectionable for country houses, if located far enough from the dwelling and below the stratum from which drinking water is obtained through pumps or springs. A better, because cleaner and more convenient contrivance, is the Dry Earth Closet, which is already much used. For rural districts, a still better method, but more costly and not everywhere applicable, is a separate system of sewerage, for a single house or a small aggregate of houses, with a disposal of the sewage immediately on the grounds, by dispersion into a sandy subsoil.*

As to the particular system of water-carriage which is preferable for our city, my conclusions are as follows:

The magnitude of the several drainage areas, from which a large amount of rain-water will accumulate at the valley lines, makes an under-ground rain-water removal a necessity, especially near their lower ends where the quantity of accumulating water will be greatest, and where, as a rule, the population is most dense, and the greatest amount of traffic is carried on.

The present gradients of many of the streets also make it a necessity, because there are numerous places where a depression is formed at an intersection, giving no possible means for the water to run off, except through under-ground channels. However much this system of establishing grades is to be deprecated, on account of the possibility of flooding the adjoining properties and causing a great fluctuation in the level of subsoil water, and for which reasons it is always carefully avoided in both the large and small cities I visited, it must, nevertheless, be considered in our city, because it exists to no small extent.

The question which now arises is whether the existing sewers can be made to fullfil the sanitary demands in removing the sewage quickly and without deposit, or whether they are only suitable for rain-water. An answer necessitates an examination of various points, which it is more convenient to state later (see Part IV), but I will anticipate the conclusion reached by saying that many of our sewers can be made to fully answer these demands. Yet it may become expedient, near the summit of the drainage areas, instead of rebuilding imperfect ones, to to use them for rain-water alone, and to build new sewers only for sewage.

*Roger Field's Plan.

It therefore appears that a combined system of sewerage is, in general, best adapted to our conditions, but that a partial application of the separate system, on account of the condition of existing works, may become advisable in some few localities.

At the higher parts of the areas extending into the suburbs, where sewers do not yet exist and where the buildings are surrounded by extensive lawns, it may also be more expedient and economical to permanently exclude rainwater from any sewers which, however, only a careful inquiry into each locality can determine. There are large tracts in the north and northwest of the city, where this can undoubtedly be done and a large saving of expense effected.

For some parts of Germantown and Chestnut Hill, from which the rainwater at present runs into the Wissahickon creek, together with the sewage, it will undoubtedly be far preferable to build the sewers for the conveyance of the latter alone and to let the rainwater run over the surface, especially when the roads become properly graded and paved. The smaller sewers can then be more readily united with the other systems, while the rainwater, without the sewage, can alone flow into the creek.

The separation of rainwater from sewage has been advocated also for extensively built-up cities,* but my experience and examinations of the localities where this system is carried out leaves no doubt in my mind that it is impracticable for our entire city. It requires a complete system of sewers for sewage alone and another one for the removal of rainwater. The expense which this duplication would entail upon so large a city is very great, not to speak of the additional care necessary to properly maintain two systems instead of one.

The towns where separation has been advantageously applied, viz., Oxford, Reading, etc., in England, are small, and in most of them old existing sewers, unfit for the conveyance of sewage were, instead of being obliterated, used as rain-water channels, while new ones, built on modern principles, served for the effectual discharge of sewage. There the expense was less by adopting separation instead of combined removal, but here it would be much greater.

From what has been said it appears finally that the different parts of the city naturally call for different treatment, and instead of applying one and the same system throughout, several systems equally

*Col. G. E. Waring, Jr., recommends it for New York in *Scribner's Monthly*, June, 1881.

good, will, if properly applied, best answer our present demands from an economical as well as sanitary point of view. For the greatest portion of our city the combined system is to be preferred. For rural districts, especially those draining into the Wissahickon creek or Fairmount pool, the separate system will, on closer examination, undoubtedly offer the greatest sanitary as well as economical advantages. Finally, in the distant isolated villages or country-seats within the municipal boundary, so-called dry-removal or private sewerage, with sewage disposal on the premises, is the most acceptable means, financially, of dealing with the problem.

It would now be in place to examine into each of these systems and their details and to trace the direct application to our city. I shall, however, in the following confine myself to sewerage proper, as the most important subject for us, leaving the treatment of isolated, or clusters of, houses, not easily to be reached by city sewers, unconsidered for the present. While the latter is confined in its bearings only to comparatively few, the former influences the public health and comfort at large, and is therefore a more proper subject for municipal action.

I shall also consider the combined and separate systems together, as most of their features are common, and distinguish between them only where necessary.

II. House Sewerage.

The removal of house sewage from the interior and immediate vicinity of dwellings is the most important branch of the system, for it is here where the effects of imperfections become most dangerous to the population. The greatest number of persons spend perhaps twenty hours out of twenty-four in houses. It is their sanitary condition, therefore, which, among external causes, mainly influences the health of a community.

In our city the attention to this subject is entirely in the hands of owners and of such plumbers and mechanics as they choose to engage for new work or repairs. Owners, as a rule, are not conversant with the proper principles according to which their houses should be drained and desire the work to be as economical as possible. Plumbers, on the other hand, are generally guided not by sanitary considerations but, as business men, very naturally, by financial ones. The result cannot be otherwise than detrimental in most cases, and has so

been found and remedied in many cities of Europe and recently in a few cities of our own country, by proper protective regulations.

In the outer sections of the city the common arrangements for a house are: a privy or cesspool at the back, in some cases even in the cellar, and a disposal of the waste water by letting it run over the surface into the gutters of a street. The cesspools or wells are lined with bricks usually laid dry, in order to allow the fluids to soak away into the adjoining soil. This system extends into such parts of the city where no sewers have as yet been built, and to dilate on its evil influences in polluting the soil and air, not to speak of the pump water still used in some of those districts, would be superfluous.

Another method is the underground conveyance of all excreta and waste water into common sewers. Where the latter were built at a later time than the houses the old cesspools, instead of being obliterated, are often retained and used as before, being connected with the sewer by a terra cotta pipe to act as an overflow.

By far the smallest number of houses are drained in a satisfactory manner, and the urgency of effecting a more general adoption of efficient methods is apparent.

Cesspools are being rapidly abolished in most of the European cities. In some they have already practically ceased to exist, as in London, Liverpool, Hamburg and Danzig. In others they are being removed and replaced by either movable casks or pails, as in Paris, numerous German and a few English cities, as Birmingham, Rochdale, Halifax, etc., or they are replaced by the construction or extension of sewerage works. In some cases a prohibitory law already exists with regard to cesspools, in others it is in contemplation as soon as they can be replaced by sewers.

A similar course should be earnestly considered here, as the continued filtration into the soil of the enormous amount of excrementitious liquids cannot but cause the most serious results in future days. Regarding the proper drainage of a house, especially in the details of plumbing, American skill has accomplished as much, if not more, than any city in Europe. In this branch, therefore, we cannot learn very much. Yet in order that not only a few, but the community at large, may benefit from this skill, and that the average house may be as well drained as it is in some cities of Europe, we should adopt a system of public control of house sewerage, to protect the owners from incompetent mechanics or improper work. Providence, R. I.,

has, perhaps, accomplished the most in this respect of all American cities. New York has recently made a successful move in the same direction, and it is to be hoped that other cities will soon follow. Regulations such as are adopted in the cities of Frankfort, Hamburg, Berlin and by the Seven Oaks Local Board, England, are attached to this report.

The most systematic regulation appears to be in Frankfort; although connecting with sewers is not made compulsory. Whoever desires to make use of them must submit plans of the entire drainage in his house for examination and approval, and the works are then carried out under municipal supervision. The result is an efficient design and good execution. In our city, on the other hand, sewer connections are compulsory under certain conditions, and the works are carried out under no supervision, and sometimes even against the desire of the owner. The result, in the majority of cases, naturally is inefficient design and bad execution.

It is evident that in this direction good legislation is much needed and should be urged. In all cities where it has been exercised great benefits have accrued. Our water and gas pipes are already subject to it for financial reasons only, and the sewer pipes should be added for sanitary reasons.

I shall not dilate on the details of house sewerage, but only indicate certain features which have a direct bearing upon the street sewers.

The sizes of the pipes need some consideration. To make them larger than is necessary is an evil, because the relation between frictional surface and bulk is increased, the stream is made shallower and deposits its suspended particles. To give proofs of this would at this day be almost superfluous. I will only mention a most striking example, shown to me in a large private mansion in London. The first sewers were about three feet in diameter, and had become gradually filled within a few inches of the top by reeking filth, while the present sewers, put in their place, were 6 and 8 inches in diameter. These have carried all the sewage, and after years have not shown the slightest deposit nor emitted any objectionable odor. The principle has been amply tested in many localities for a long time. Lately, Col. Waring has recommended a maximum diameter of 4 in. for house pipes in Memphis. When I state the fact that the dry-weather flow

*See Appendix No. 3.

in our Mill creek sewer, which is 20 feet in diameter, and drains an area of over 3000 acres, could run through a 10-in. pipe, the absurdity of using this same size for a single house becomes apparent, and the effects cannot be other than to cause deposits in the pipes. Our plumbers usually put in 8-in. pipes, often 10-in. and sometimes 12-in. There are instances here where even 18-in. and 20-in. pipes were laid to drain a single house, and the consequences cannot be dissimilar to those in the London mansion just mentioned.

If street sewers are not to be obnoxious, the house sewage must be delivered into them while it is fresh. When they receive liquids and solids that have already become foul in the houses, the escape of deleterious gases is difficult to prevent. Smaller sizes, certainly no larger than 6-in., properly planned and laid, would therefore aid in improving not only the condition of the private sewers, but also that of the public sewers.

Another point can directly effect the street sewers, namely, that of the ventilation of house pipes. Without entering further upon this subject here, I will only state, that one of the most efficient methods, tested by long experience, is that of ventilating street sewers partially through the soil pipes of houses. It is done in the best drained continental cities, as Berlin, Hamburg, Frankfort, Danzig and others, lately also in Memphis, Tenn., and promises to be, at least for small sewers, a very satisfactory way of assisting the exchange of air. The soil pipe is carried above the roof, and the main trap, usually inserted where the sewer leaves the premises, is omitted, which gives a free passage for the sewer air. Injurious effects cannot be caused hereby, as the gases created in house pipes are, as a rule, more obnoxious than those forming in street sewers, and if the former prevent an improper escape of their own gases they will also prevent an escape of the others. To use rain-water pipes for ventilation is improper, not only because they hinder the escape of air at times of rain, just when it is required by sewers filling up and expelling it, but because they are not as tightly joined as soil pipes, and may effect the air entering the garret or other windows.

Ventilating sewers through the soil pipes of private houses are also specially beneficial for the latter, because they provide for a constant circulation, which could not be otherwise obtained, except by a special opening to the air in their lower part, which is not always acceptable.

The gain which this aid to the ventilation of the entire street system produces is sufficiently great to demand at least serious consideration.

The value of puplic control here, too, becomes apparent, because a single property owner is not interested in ventilating the street sewers nor would ventilation through soil pipes be very efficacious, unless the system were adopted in all houses.

It must finally be stated, what differences will be required in the arrangement of house drainage, when the general system is a combined or a separate one. For the latter, no rain-water should be admitted into the sewers receiving the house-water, unless a small portion is deemed expedient for flushing purposes. For such localities in the suburbs of our city, where the separation would be appropriate, special rain-water sewers would hardly be required on account of their rural character, and the water could run over the surface as heretofore. If, however, expense is not an obstacle, special drains, if desirable, can still be laid in such localities on private ground, but then discharge the rain-water into the gutters of the street.

(To be continued.)

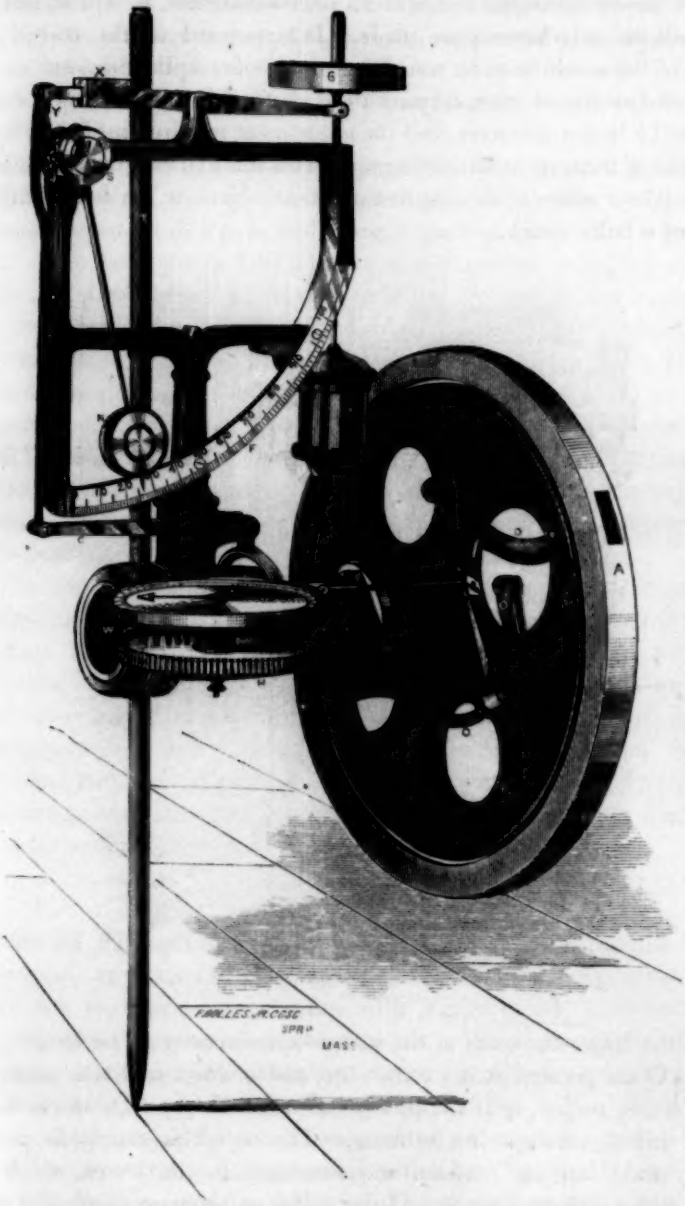
Electric Light by Water Power.—Sir Robert Kane estimates the water power in Ireland as equivalent to at least one and a quarter millions horse-power. He recommends the adoption of Grierson's plan for utilizing the power, by means of electrodynamic machines. When the cost of the machines has once been paid the running expenditure will be trifling. The system has already been tested in the village of Godalming, which is traversed by the Wey, where the power of the river has been successfully applied to the illumination of the streets by electric light. It would be easy to repeat the experiment in some other village of greater importance, and there is no doubt that the result would be equally favorable. Dublin, for example, surrounded by two fine canals, and traversed by the Liffey, is admirably situated for conclusive and economical experiments. The adoption of Grierson's project would undoubtedly be very advantageous for Ireland. It could also be applied in Paris, where the utilization of the Seine ought to be tried. Our electricians who have already illuminated certain portions of the capital would render an immense service to the citizens by giving them an illumination which is more certain and more economical than gas.—*Les Mondes*, xxxi, 546. C.

EMERSON'S POWER SCALES, OR DYNAMOMETER.

By Jesse H. Lord.

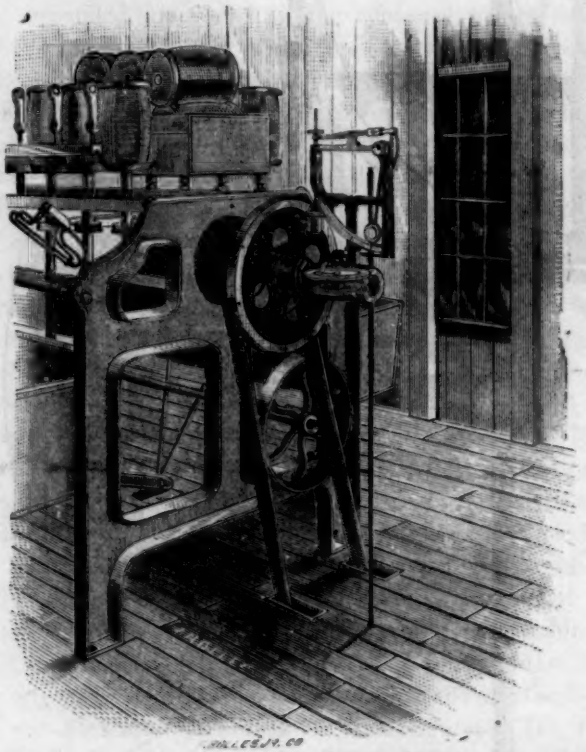
A number of attempts have been made to construct a power measurer which should give absolute results in foot-pounds; but most of them had some inherent defect, either in construction or application. Some have depended upon springs for efficiency, others have been intended for fixtures; most of them gave only relative results, and none of them were simple, portable, easily applied attachments. So many mechanics insist on a resort to the Prony brake as preferable to any and all so-called improvements. Yet a good dynamometer is unquestionably to be desired, as a useful implement to the manufacturer, millwright, the leasor, and to the hirer of power. James Emerson, of Willimansett, Mass., has perfected a power scale that appears to possess all the requisites desired. Unlike most other power measurers, this demands no change in the machine or shaft to which it is applied, beyond the removal of one of the pulleys, if a tight and loose pulley are used, the pulley-arms serving as means of propulsion or actuation of the power measurer. No springs are used on the machine, and all the movements are direct and absolute. No comparison with some other standard is required, as this machine gives absolute results instead of relative indications. It short, it is a power scales, and really weighs the "strain," "resistance," "friction," or "inertia," just as truly as the Fairbanks scales weighs the gravity of a load; and, like the Fairbanks scales, this may be considered a standard. The elements of its operation are speed of the machine, to be weighed or measured in feet, and resistance of the machine in avoirdupois pounds. Both these data are given by the appliance at the same time, and both are represented in plain figures. The result of the two multiplied together is the number of foot-pounds, which may be easily reduced to horse-power or its fractions if this is desired.

The larger engraving represents the power scale detached, and the smaller engraving shows it attached to a machine from which the loose pulley has been removed, and the tight pulley is made a loose pulley by having its set-screw slacked up or its key removed. The utility of this remaining pulley is to receive the driving belt, that the machine to be tested may be run at its normal speed.



EMERSON'S DYNAMOMETER.

The power scales has a disc of 12 inches diameter, to which, and its hub, all the attachments are made. It is secured to the end of the shaft of the machine to be tested by means of a split threaded sleeve with wedge-shaped jaws, formed to fit shafts from $\frac{1}{8}$ of an inch diameter to $1\frac{5}{8}$ inches diameter, and the adjustment requires but two or three minutes of the time of an intelligent workman. In fact, the adjustment of the power scales is similar to that of an object to be bored in the jaws of a lathe chuck.



In the larger cut some of the letters of reference may be of use; the levers O are pivoted at A in the disc, and connect with the arms of the driving pulley, or if the pulley has a solid web, with the sides of holes drilled through the webbing. The object is simply to give a rotary and "bearing" motion and resistance to the levers, which by bell cranks connect with an annular collar on the power scales, so as to actuate the lever C by the yoke K, that gives movement to the pen-

dulum N. This connection between the rotating movement of the shaft of the machine to be tested, and the reciprocating motions of the pendulum and the lever C, is similar to that of the old-fashioned throttle governor of the steam engine, and can be readily understood by all mechanics.

The marking scale beam of this power measurer is exactly like that of the Fairbanks' scale in principle, being modified only by having a pendulum instead of a *pois*, and being a quadrant instead of a straight line. The letter shows how adjustment for perfect balancing can be made; G shows how weights may be added to increase the capacity of the power scales, this 12 inch size being capable, at 1,000 revolutions per minute, of weighing up to 25 horse-power, other speeds proportionally, and the letters W and H show the method by worm and gear of getting the number of revolutions of the machine to be tested. A staff, T, or a pointed bar, is used to rest on the floor to prevent the friction of the shaft from moving the pendulum and scale out of a perpendicular, and the dash-pot X combines with the adjuster-block X to prevent undue oscillation of the pendulum.

The total weight of this size apparatus is so slight that it may be carried easily under the arm, and its readiness for use is such that ten minutes is amply sufficient to apply and adjust it. No previous schooling or drill is required to enable an overseer or boss to apply this power scales, as is necessary in indicating a steam engine; and yet this apparatus is intended to do for the manufacturer, and for the hirer and the letter of power what the indicator does for the proprietor of steam-power,—give the facts about the amount of power used and its cost; and this it does with accuracy.

Use of Phosphor-Bronze for Electric Transmission.—The successful experiments with phosphor-bronze for telegraphic wires have led to various speculations with regard to an extension of its employment for other electrical purposes. When the transmission of force to a distance by electricity comes extensively into use, wires will not only be required for its conveyance, but there will also be a need of dynamo-electric machines rotating at immense speed. It will then be important to have bearings which heat but slowly, and which are not readily worn by friction. These qualities are possessed by phosphor-bronze in an eminent degree.—*L'Electricien.* C.

MECHANICAL MODIFICATIONS OF THE BESSEMER PLANT NECESSARY TO ADAPT IT TO THE ECONOMICAL WORKING OF THE BASIC PROCESS.

By William M. Henderson, M.E.

The most difficult problem which has presented itself in the solution of the basic process is undoubtedly the vulnerable character of the refractory lining of the converter. The importance of having some prompt, unlaborious way of renewing the linings will be best understood by referring to the fact that while a converter for conducting the ordinary Bessemer process requires renewal about every three months, a converter for the basic process requires renewal about every sixty hours, and as the relining of such a converter occupies from fifteen to twenty hours, the quicker it is effected the better for the output and the cheaper for the product.

Of the methods which have been proposed, one is to double the entire converting plant, and do all the repairs to the converters and reline them where they stand; but this is obviously very costly, both as regards outlay and waste of room; it is besides exceedingly inconvenient. The primary object of the converting department being to produce ingots, is not the place to repair refractory linings. Whenever a vessel is unfit for steel making it should be removed at once out of the way and replaced by another ready to continue the work, in the same way as the ladles and vessel bottoms are at present handled. The same may be said of stripping the ingots after the moulds are filled. They should be taken out of the converting department at once to a stripping room furnished with suitable cranes and other hydraulic appliances specially arranged for the purpose, doing away with all the confusion now existing and brought about by stripping the ingots in the pits in front of the converters, seriously interfering with the business of making steel, a matter which should be separated completely from the work of repairs, etc.

Another plan proposed is to replace each entire converter by lifting it bodily out of its trunnion bearings by a powerful overhead traveling crane and conveying it away to the repair shop, and bringing another in working condition by the same means to take its place.

It is apparent this must be an exceedingly slow and tedious operation. First removing the heavy nuts from the pillow block caps, then the caps themselves, and then bringing the carriage of the traveling crane directly over the converter so as to lift it squarely out of its bearings, and making fast a chain capable of lifting thirty tons; the time consumed in taking it away, depositing it, casting loose and repeating, in an inverse manner, all these operations with the repaired one will not show very favorably for this method. I am informed this arrangement is in actual use in Europe and has been patented in this country.

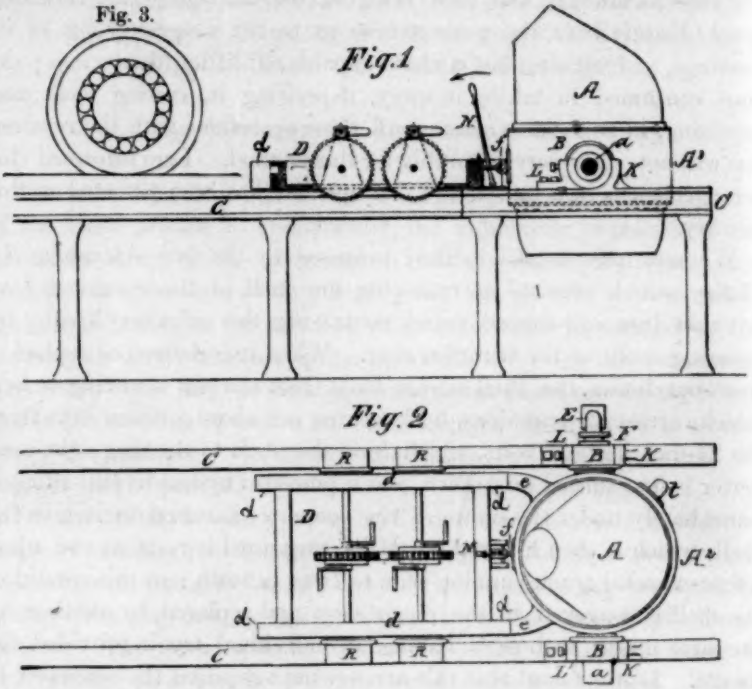
We now pass to the method proposed by the late Alexander L. Holley, which consists in removing the shell of the converter (the wrought iron egg-shaped vessel containing the refractory lining) by lowering it out of the trunnion ring. When it is desired to replace a worn-out lining, the shell is cast loose from the cast iron ring or belt which carries the trunnions, by knocking out about a dozen keys from the 2½-inch vertical bolts, which bind the shell to the ring; the converter is first turned nose down, and a powerful hydraulic lift, situated immediately under the centre of the converter is raised to receive the shell, which is then lowered out of its ring until it rests on end upon a four-wheeled truck running on a railway beneath; in this condition the shell is conveyed to the repair shop and replaced by another by the same means, each shell having an individual truck provided for its use. It was found that this arrangement required the converter to be hung about 20 feet above the general ground level in order to give room to lower the shell out of the trunnion ring and to remove it laterally, requiring a second hydraulic crane and ladle in order to get the charge down to the working level.

To obviate this difficulty Mr. Holley took out a subsequent patent for removing the pillow block caps, disconnecting the shell as before, and hoisting the entire trunnion ring, by tackle, clear over the top of the converter, so that the shell could be removed laterally without being lowered. Here we fall back again, encountering some of the objections found in plan number two, and it must be admitted dismantling a red-hot converter where it stands is not a commendable feature.

Such is the history of the appliances devised for removing the linings of converters adapted to the basic process, up to the time the

writer obtained a patent for the same purpose, which will now be briefly described.

Fig. 3.



Figs. 1 and 2 of the accompanying engravings show a side elevation and plan of this improvement, in which *A* is the converter, substantially the same as other converters. The improvement consists in turning the ordinary pillow blocks, in which the converter trunnions revolve, into flanged wheels, *BB*, by means of which the converter may be run in and out of working position for use and for repairs, the track consisting of the girders, *CC*, usually provided, and they may be arranged to communicate with such sidings or turnouts as may be found necessary to provide room in the repair shop for their reception. When the converter is in working position the flange wheels are confined between fixed stops, *KK*, on the girder, and removable chocks, *LL*, secured by keys and bolts as shown; the wheels, thus secured, become to all intents and purposes pillow blocks, as before, in which the trunnions can revolve when the converter has to be tilted; this tilting of the converter is accomplished by the usual

rack and pinion motion, operated by a hydraulic cylinder not shown on these cuts.

The power truck, *D*, for traversing the converters, is provided with two axles, each having a pair of flanged wheels, *RR*, which follow the same track as that provided for the converter; a spur wheel, keyed on each axle, gears into a pinion on a shaft carried by suitable frames secured on the truck, provided at each end with a crank handle. The side beams, *dd*, of the truck, project from each end of the same, and are arranged to abut against projections, *ee*, on the converter, a hook, *f*, on the latter being adapted for coupling by a link to a pin in the truck, a rigid connection being effected by means of the lever, *N*, which is pivoted to the truck. Thus by forcing the lever in the direction of the arrow the truck must be made to bear hard against the projections, *ee*, before the coupling pin can drop into its place. When the truck is thus coupled to the converter it forms with it a vehicle which may readily be wheeled away.

The diameter of the converter wheels to suit the present height of trunnions above the girders would be about 30 inches. The diameter of the tram wheels may be the same, and the same diameter will answer for the gear wheels. Driving pinion $5\frac{7}{8}$ diameter, 12 teeth; diameter of gear wheels 30 inches, 63 teeth, $1\frac{1}{2}$ pitch, $3\frac{1}{2}$ face; proportion of gearing 5 to 1; leverage of crank over pinion 5·44. With two men stationed at the cranks, each exerting 18 pounds against the handles, we have 18 lbs. $\times$ 5·44 = in round numbers, 100 lbs. $\times$ 5 (proportion of gearing) = 500 lbs. $\times$ 2 men = 1000 lbs. If the initial resistance to be overcome to start the load is taken at the fair allowance of, say, 20 lbs. per ton, the force here expended would be equivalent to moving a converter weighing 50 tons, and as the converter would weigh, empty of metal, and with the bottom removed, about 30 tons, a fair margin is left for those obstacles in the way which no amount of calculation can provide for. At 16 revolutions of handle, the car conveying the converter would travel 24 feet 6 inches in one minute. By arranging friction rollers between the journals of the trunnions and their bearings, as in Fig. 3 the friction may be very greatly reduced. The friction of trunnion journals in their bearings being a species of sliding friction, following a circular path instead of a plane, the coefficient is slightly different, but sufficiently analogous that the following experiment may be accepted as a fair exponent of what would follow by the use of friction rollers.

I took two smooth planed surfaces, wiped clean with oily waste, the upper weighing 363 lbs., to which was attached a cord leading over a pulley; it took a weight of 62 lbs. on the end of the cord to move the plate by sliding, about $\frac{1}{6}$ of the weight. I then placed fourteen one-inch smooth rollers $7\frac{1}{2}$ inches long in contact with each other, similar to the sketch, under each end; the plate was then moved by $3\frac{1}{2}$ lbs., the 100th part about of the load, and by comparison, about the $\frac{1}{18}$ part of what was required for sliding.

The effect of friction rollers in lessening the friction of the trunnions of a converter in their bearings is of such a marked character that I would strongly recommend their use even to existing converters; the ponderous hydraulic cylinder now necessary to revolve the converter could be replaced by one of much smaller dimensions. From this it will be seen that by the use of friction rollers the force required to transport a converter may be greatly reduced, and by their use it is plain the very largest converter possible to be made or used could be handled with ease.

The more prominent advantages claimed for this method of renewing the linings of converters for the basic process over the removable shell system are as follows:

1. It dispenses with the necessity of having the converter raised to the impracticable height of about 20 feet above the general ground level.

2. It dispenses with the necessity of having a special hydraulic lift, extra powerful and long stroke, for raising and lowering the shells.

3. It dispenses with the necessity of having an intermediate ladle and crane between the converter and the ingot ladle to get the charge down to the working level.

4. It removes the converter track completely away from the debris and great accumulation of slag thrown off by the basic process and the refuse dumped below at the end of each heat.

5. It provides room underneath the converter for the introduction of the gas main, and pipes to rapidly dry the converters after relining.

6. The converter being made to connect again with a hydraulic cylinder and rack in the repair shop, is as manageable undergoing relining and repairs as when working. It can be turned round to any desired position, greatly facilitating relining and repairs.

7. Another advantage is the ease and rapidity with which a converter can be set free for removal, and replaced by another in working

condition, by the simple removal of two chocks, which lock the wheels in working position, reducing the labor to be done in the coverting department on a red hot vessel to the minimum.

Steelton, June 10, 1882.

ON THE PREVENTION OF FIRES IN THEATRES.

By C. John Hexamer.

[A paper read at the Stated Meeting of the Franklin Institute, held June 21, 1882.]

(Concluded from page 134.)

But plugs should not be solely relied upon for protection in theatres, from the fact that their usefulness depends entirely upon the courage of the employés. It is too much to ask a man to stand and fight fire when he knows that there is a tinder-box between himself and safety, and that at any moment a drifting spark may cut off his only chance of escape. Sometimes such heroes do exist, who pay for their bravery with their lives, but these are only warning examples to others not to risk their own in similar efforts.

In this case we must again take our resort to automatic means, and for this purpose automatic sprinklers, which have been in use in mills for some time, would be of great value.

As a plentiful supply of water is not always at hand, and as steam-pumps frequently get out of order, large reservoirs should be placed on top of theatres. These should be placed on top of the auditorium and not in the rigging-loft The stage, as the most inflammable part, being generally ignited first, would (if the reservoirs were placed on it) deprive the remainder of the building of water.

In order to keep the water in these tanks from freezing, the exhaust-steam pipe of the engine should be made to pass through it; or, as this is not always convenient, it should be mixed with salt (salt water having a lower freezing-point than pure water). The addition of salt would also have the wholesome effect of preventing the formation of algæ (the green slime found on ponds and other still water), which are obnoxious by their smell and by the tendency they have of closing the pipes.

Every theatre should have a fire brigade consisting of at least five

men; these should be present at all performances, and should be perfectly familiar with the theatre and all its fire appliances.

At Carlsruhe (the seat of the famous polytechnic school) the authorities, after the great fire of the "Hoftheater," organized a fire patrol of students. These are stationed all over the theatre, know all appliances, and, as a corps of gentlemen, must be much superior to ignorant men, both in case of fire and in quieting a panic.

Watchmen should be constantly on the premises, and, to control them, watch-clocks should be fixed in different parts of the building.

Automatic fire-alarms, placed in various parts of the stage, would be of great use, as the fire department is generally notified too late.

We now arrive at the most important question: *The safety of audiences.*

From the numerous accounts of theatre fires which the author has collected he finds that loss of life is caused by (1), suffocation by smoke; and (2), the crushing and trampling of the panic-stricken masses.

Experience shows that death is mostly caused by suffocation, and that the burning of bodies is a subsequent occurrence, taking place after life has already become extinct. This was again clearly illustrated by the late Vienna fire, as will be seen from the following account of a civil engineer, given at the time, in several Vienna papers:

"This gentleman, with his wife, was sitting in the second gallery, and, fortunately for himself, was one of the first to discover the fire; they quickly got up and walked out, while the majority of the audience had no idea of the occurrence. The lights were burning until they reached the last steps of the second story, when all lights were suddenly extinguished. While they were still in doubt in what direction to go, they were carried, by a sudden rush, to the right, and found themselves in front of a glass door. This door was broken open, when they saw that they were, with some twenty-five other persons, on the balcony fronting on the '*Hessgasse*' (Hess Street).

"The gentleman, seeing his wife safe, returned to the corridor and loudly shouted: 'This way for safety!' He received no answer. He then went further, until checked by the smoke, but already, at this short distance, saw several corpses. Thereupon he went back to the balcony and saved himself by jumping on the cloths in the street."

He concludes from this that after this short time, already, every one in that gallery was suffocated. Although we cannot tell how long it took to suffocate all these people, we can safely state that they were

suffocated and not burned to death, the bodies having been burnt later.

We must, therefore, get rid of the smoke in the quickest and best manner possible. This question has been solved by the ingenious device of Hofman, which acts in conjunction with his automatic drop curtain, and by Mr. Louis Sues of Chicago.

The intense smoke in the auditorium, during a fire on the stage, is caused by a draft of hot air from all parts of the house towards the open doors and ventilator.

The latter is usually situated above the main chandelier in the centre of the auditorium ceiling. This draft may frequently be noticed by the sail-like outward bulging of curtains.

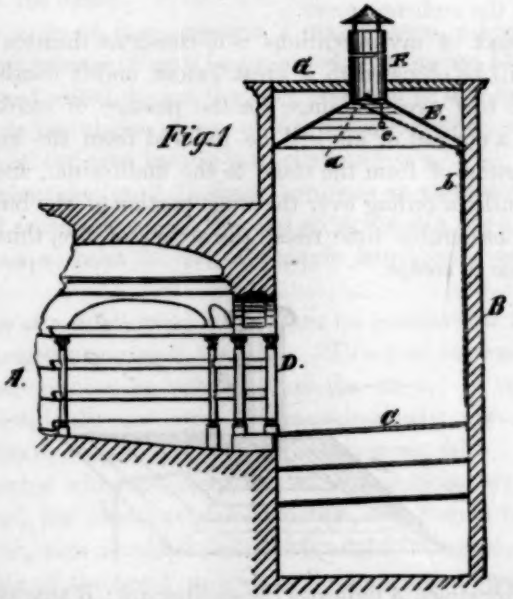


Fig. 1

We must, therefore, form a counter draft which, in case of fire, would be strong enough to overcome the combined action of the doors and ventilator.

This could best be accomplished by a chimney or flue on the top of the stage which would take off all smoke and cinders. Or, as before stated, *making a perfect shaving vault of the stage.*

We will now describe the different solutions advanced for this problem, beginning with the simplest.

A good idea was suggested a short time ago by one of the inspecting chiefs of the New York fire department. It was, to make the roof over the stage a vast skylight, the glass of which could be broken in case of fire and a draft thus created which would carry the flames upwards and prevent them spreading to the auditorium.

Next in order comes Mr. Sues' smoke flue, the description of which I quote from his patent specification. Fig. 1 is a vertical section. Fig. 2 is a detail in perspective.

"Theatres frequently take fire and in almost all cases the fire originates in that portion of the building devoted to the stage and scenery. There is usually a draft from the stage to the auditorium, especially when the doors are opened and the flames and smoke pass rapidly from the stage to the audience-room.

"The object of my inventions is to construct theatres so that this difficulty will be obviated to a great extent, and it consists in a large outlet in the roof over the stage for the passage of smoke in case of fire, so that a current of air will be induced from the auditorium to the stage instead of from the stage to the auditorium, and combining with such outlet a ceiling over the stage portion of the building which will for a considerable time resist the action of fire, thus giving the audience time to escape.

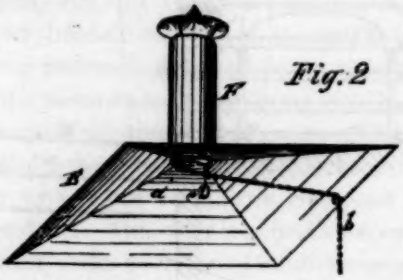


Fig. 2

"In the drawings, *A* indicates the auditorium; *B* that portion of the building devoted to the stage; *C*, the stage; *D*, opening between the stage and the auditorium; *E* is the ceiling over the stage. This ceiling I make practically fire-proof, either by making it wholly of metal or by the use of metal joists with wire or wire-cloth for lathing, and usual plastering, or in other suitable manner. *F* is a large passage to be made of fire-proof material. It passes through the roof *G*. Its lower end is properly secured in the ceiling and is open, except when closed by the valve *a*. *b* is a chain by means of which the valve *a*

can be opened. *c* is a weight which holds the valve in position when closed.

"The operation is as follows: If a fire breaks out upon the stage the valve *a* is to be immediately opened. The ascending heat and smoke will rise to the ceiling and escape through *F*, thereby producing a current from the auditorium to the stage, instead of the reverse, thus keeping the smoke and flames from the audience-room while the audience is escaping. In cases where a fire-proof drop-curtain is used suitable openings may be somewhere provided to admit air to the stage.

"In theatres of the usual size the passage *F* should be about six feet in diameter. It may be carried some distance above the roof which will increase the draft.

"Two or more of these passages *F* may be used. The opening at the top of the passage *F* may be protected from storms by caps."

This is an excellent device, the only objection to it is that it is not automatic; its usefulness, in case of fire being, therefore, dependent on the coolness of the men having it in charge.

The ingenious device of Hofman combines an automatic wire drop-curtain, and automatic smoke flue and an automatic fire alarm. This device will act without the aid of a single hand, being entirely automatic.

It consists of a safety-rope, which runs on pulleys over the principal and most dangerous parts of the stage. This rope is prepared so as to be the most combustible substance on the stage. In case of fire, it will, therefore, ignite and burn off almost instantly. Has this moment arrived, a heavy weight, held by the safety-rope, falls. This weight being connected with the machinery of the curtain by a lever, the lever is raised, the machinery set in motion, and the curtain lowered. Not, however, with a sudden fall which might damage it, but steadily.

The falling of the heavy weight, at the same time, opens the valve of the large smoke flue contained in the roof of the stage, whereby the smoke and heat of the fire is kept on the stage and taken out of the flue; thus giving the audience time to leave the theatre quietly and orderly, without being threatened by smoke or heat. The same moment the above takes place the fall of the weight sets a fire alarm in motion and the fire department is notified.

We have now seen the different devices for getting rid of that greatest danger to audiences—smoke—and can now compare their

relative values. The first would be very simple, but in the time required for the firemen to arrive and break in the glass of the skylight, the audience might be suffocated.

The second is an excellent patent, its only objection being, as before stated, its want of automatism.

The third, to the author, seems undoubtedly the best, for if in case of fire, the men having it in charge should neglect to open the valve, it would act automatically; not to speak of the immense value of the automatic wire drop-curtain and fire-alarm.

The writer has frequently noticed the time required by audiences to vacate theatres, and out of numerous experiments finds it takes from $3\frac{1}{2}$ to 11 minutes for a theatre to be entirely emptied. But this time is protracted indefinitely in case of a panic. It has been found that in cases where audiences had ample time to vacate theatres many were killed, although not prevented from escaping by the smoke.

This is explained by the jamming of crowds in corridors. A mass of people may best be compared with a number of logs floating down a stream, which at some point, by their mutual pressure, form arches across it, thus becoming wedged fast. In the same manner persons form arches across corridors which are sometimes broken, only to be formed again.

This, the cause of many deaths, may be remedied by making the walls of corridors inclined towards each other, being narrowest in the theatre and widening towards the exit doors, as it is impossible for logs to jam in a widening water-course.

There should be outlets from each gallery or floor separate and distinct from every other outlet, so that a crowd from one gallery cannot precipitate itself upon a crowd from another floor that is struggling to get out.

A matter still sometimes neglected is, that all doors should open outwards, the people of the fourth gallery at the recent Vienna fire, for example, were hindered from flight by the doors opening inwards.

Most theatres have a sufficient number of exits, but in order to save doorkeepers most of them are locked; some not being satisfied with locking them, even nail and bolt them shut.

Corridors are also frequently too narrow; these should never be less than eight feet broad, which would allow, at most, but five persons abreast.

Another outrage to humanity are high galleries. In American

theatres there are never more than three, but in Europe they have as many as five.

Law should forbid the erection of more than two galleries, *i. e.*, a "balcony" and "family circle."

The horrors of theatre fires are always increased by the total darkness which envelopes audiences a short time after commencement of the fire.

This is frequently caused by the explosion of gas on the stage. To obviate this, all theatres should separate the system of lighting the auditorium from that of lighting the stage.

After years of hard work, the authorities of Vienna succeeded in compelling managers to have oil lamps in corridors. The order was complied with, but, as was seen by the late catastrophe, these were never lighted.

It has frequently been urged, especially by "insurance men," that the risk from fire would only be increased by the use of coal oil in these lamps. But it is not necessarily said that petroleum must be used, for any of the heavy oils (used long before coal oil was known) might be employed with advantage.

If these should be objected to, let it be remembered that festivals which outrival everything in history by their splendor, and that the plays of a Corneille and a Moliere were first produced before the eyes of the then most powerful king of Europe, by the light of *candles*. Why should these then not satisfy us in the humble position of safety corridor lights?

Particular attention should be paid to the calamity at Carlsruhe in 1847. By the inattention of one of the servants in lighting the gas the drapings of the Grand Ducal box caught fire. All parts of the house were crowded, over 2000 persons being present. The flames instantly spread to the balcony; every one tried to escape in the greatest hurry. The audience of the parquet, as well as that of the balcony, saved themselves, but the greatest confusion ensued in the higher galleries which were in a short time filled with smoke.

Of the four exits, but the one under which the fire broke out was open. Every one rushed to this exit and very soon it was jammed shut. The scenes following were indescribable: A few climbed or jumped from the galleries; others threw themselves out of the windows; many were crushed to death, and most were suffocated by the hot smoke.

In the narrow corridors people were lying in heaps. To this was added that immediately after the breaking out of the fire the gas was turned off from the street and the building thrown into total darkness. The situation of the people, jammed fast in corridors, without light, enveloped in smoke, was frightful.

This catastrophe cost the lives of sixty-three persons, and over two hundred were terribly wounded.

As before mentioned, the theatre had four exits, but to save the expense of extra doorkeepers three of these had been closed for years, and not only locked, but nailed and boarded shut, and but few knew the existence of these extra exits.

One cause saved the lives of many—gas had not long ago been introduced and on this account many oil lamps had been retained to do duty in corridors. These lamps, which had been the objects of wit and sarcasm, saved the lives of hundreds.

We had at Vienna the counterpart of Carlsruhe, only in this case the lamps were not lighted or hundreds of unfortunate victims would have been saved.

It can, from this, be seen how necessary oil lamps are and that in the deciding moment this precaution will save many lives.

Before concluding my remarks it may be well for me to give an example of a theatre, which was managed in the correct manner, which had many of the modern improvements, and which at the same time is the first case on record in which *the entire* audience of a burning theatre escaped in safety. On the 16th of April, of this year, during a performance of the farce "Robert and Bertram," at the "Hof-Theater" of Schwerin, the cry of fire was suddenly heard from one of the galleries. As no flames or smoke were perceived the audience remained seated, until the news came from the outside that the roof was burning. The Grand Duke, who was present immediately addressed a few words to the audience and ordered the musicians to continue. The stage-manager also assured the audience that there was no danger. But soon the wire curtain had to be lowered, and now the audience left the theatre in the greatest order, especially the densely packed galleries were rapidly cleared, the audience escaping through the numerous exits, *which were all open*. For some time previous to the occurence audiences had been instructed—by means of large placards hung up in the corridors—how to act in case of fire. The *oil-lamps were all lighted*, and the wire-curtain was in *good working order*,

thus for the first time, practically illustrating its use. On account of these excellent arrangements it was possible for the whole audience to save itself, although many ladies and children were present. Here we then have an example to show how, with proper precautions, faithful employés—especially the man who let down the wire-curtain—and cool, collected conduct, an audience may be spared the dangers of a theatre-fire. The beautiful theatre burned down, also the large Concert Hall attached to it. But the only life lost in the event was that of a fireman who was buried under a falling wall, this occurring a considerable time after the audience had escaped.

The author hopes to have shown how theatres can be built, although not fire-proof, yet in a manner so as to give safety to audiences.

Theatres *could* and *should* be built so that the largest audiences could escape in safety.

THE CHEMISTRY OF THE PLANTÉ AND FAURE ACCUMULATORS.

By J. H. Gladstone and Alfred Tribe.

Part I.—Local Action.

Among the important discoveries of late years few have claimed so much attention, or have been so full of promise for practical use, as the accumulator of Planté and its modifications. Our attention was very naturally directed to the chemical changes that take place in these batteries, especially as it appeared to us that there must be certain analogies between them and some actions which we had previously investigated. In the present communication we propose to treat merely of one point—that of local action, leaving the fuller discussion of the subject to some future occasion.

It is well known that metallic zinc will not decompose water even at 100°C., but we found that zinc, on which copper had been deposited in a spongy condition, was capable of splitting up the molecule even at the ordinary temperature, oxide of zinc being formed and hydrogen liberated. If placed in dilute sulphuric acid it started a very violent chemical action, sulphate of zinc and hydrogen gas being the result. We termed the two metals thus conjoined, the *copper-zinc couple*, and this agent was fruitful in our hands in bringing about other chemical

changes which neither metal singly would effect. Electricians will readily understand the nature of this agent, and will recognize in its effects only a magnified form of what we are all familiar with under the name of *local action*. Now the negative plate of a Planté secondary battery is a sheet of lead, upon which finely divided peroxide of lead is distributed. It is well known that the electromotive force of lead and lead peroxide in dilute sulphuric acid is nearly three times that of zinc and copper in the same liquid. We were therefore induced to think that the plate must act in the same way as our copper-zinc couple. We found such to be the case. If a plate so prepared be immersed in pure water the decomposition of the liquid manifests itself by the reduction of the puce-colored peroxide to the yellow monoxide. There could be little doubt therefore that the lead peroxide couple, if we may call it so, would decompose sulphuric acid, with the production of sulphate of lead. This also was found to be the case.

As the destruction of peroxide of lead means so much diminution of the amount of electric energy, it became interesting to obtain some definite knowledge as to the rapidity or extent of this action.

When the peroxide of lead on the metal is very small in quantity, its transformation into the white sulphate goes on perceptibly to the eye, but when the coating is thicker, the time required is, as might be expected, too long for this kind of observation. In one experiment, following the procedure of Planté, we formed the peroxide on the plate by a series of seventeen charges and discharges, or reversals, each operation lasting twenty minutes, and the time was further broken up by seven periods of repose, averaging about twenty-four hours in length. After the last charge we watched the local action taking place, and found that the whole of the peroxide passed into white sulphate within seventeen hours. In another experiment the two plates formed according to Planté's method were immediately joined up with the galvanometer, and deflection noted. They were then at once disconnected. After the repose of one hour they were joined up again, and another observation taken with the galvanometer. This was repeated several times, with the following results:

Initial strength of current,	100
After 1 hour's repose,	97
" 2 "	40
" 4 "	14
" 17 "	1.5

It results from this that during each of the long periods of repose recommended by Planté the peroxide on the lead plate is wholly, or almost wholly, destroyed by local action, with the formation of a proportionate amount of sulphate. But this is not, as it would seem at first sight, a useless procedure; for, in the next stage, the sulphate is reduced by electrolytic hydrogen, and by a process which we hope to explain when discussing the complete history of the reaction, the amount of finely divided lead capable of being peroxidized is increased. That this is actually the case is shown by the following experiment. The peroxide formed on a lead plate by first charging was determined and called unity; it was allowed to remain in a state of repose for eighteen hours, charged a second time, the peroxide again determined, and so on:

Separate periods of repose.	Charge.	Amount of peroxide.
——	First	1·0
18 hours	Second	1·57
2 days	Third	1·71
4 "	Fourth	2·14
2 "	Fifth	2·43

In other trials, following the procedure of Faure, we employed plates in which the peroxide was formed by the reduction of a layer of red lead (containing 51 grains to one square inch of metallic surface) and subsequently completely peroxidizing the spongy metal so produced. In one series of experiments we left the peroxidized plates to themselves for various periods, and determined the amount of sulphate formed. This gave us the amount of peroxide consumed.

Experiment	I,	after	2	hours	7·2 per cent.
"	II,	"	3	"	15·1 "
"	III,	"	4	"	19·8 "
"	IV,	"	5	"	30·0 "
"	V,	"	24	"	36·3 "
"	VI,	"	7	days	58·3 "
"	VII,	"	11	"	67·3 "
"	VIII,	"	12	"	74·3 "

The last experiment was tested with the galvanometer during its continuance, as in the case of the plate formed by Planté's method, with the following results:

Initial strength of current				100
After	1	day's	repose	92
"	3	"	"	79
"	4	"	"	34
"	5	"	"	24
"	7	"	"	11
"	9	"	"	8
"	12	"	"	1

It is evident from these observations that a lead-peroxide plate gradually loses its energy by local action, and that the rate varies according to the circumstances of its preparation.

Two difficulties will probably present themselves to any one on first grasping the idea of this local action: 1. Why should a lead plate, covered with the peroxide and immersed in dilute sulphuric acid, run down so slowly that it requires many hours or even days before its energy is so seriously reduced as to impair its value for practical purposes? In the case of the copper-zinc couple immersed in the same acid, though the difference of potential is not so great, a similar amount of chemical change would take place in a few minutes. 2. In a Planté or Faure battery the mass of peroxide which is in contact with the metallic lead plate expends its energy slowly. How comes it to pass that if the same mass of peroxide be brought into connection through the first lead plate with another lead plate at a distance, it expends its energy through the greater length of sulphuric acid in a tenth or a hundredth part of the time?

The answer to these two questions is doubtless to be found in the formation of the insoluble sulphate of lead, which clogs up the interstices of the peroxide and after a while forms an almost impermeable coating of high resistance between it and the first metallic plate.

The following conclusions seem warranted by the above observations:

In the Planté or Faure battery local action necessarily takes place on the negative plate, with the production of sulphate of lead.

The formation of this sulphate of lead is absolutely requisite in order that the charge should be retained for a sufficient time to be practically available.

The rapidity of loss during repose will depend upon the closeness of the sulphate of lead and perhaps upon other mechanical conditions. These are doubtless susceptible of great modifications. We do not know how far they are modified in practice, but it is conceivable that still greater improvements may yet be made in this direction.

Part II.—The Charging of the Cell.

In the preceding article we directed attention principally to the local action that takes place on the negative plate of a Planté or Faure battery. We pointed out the close analogy between zinc coated with spongy copper, and lead coated with spongy peroxide, in their action on water or dilute sulphuric acid; and we showed the importance of the lead sulphate produced in moderating this action. We now propose to treat of the chemical changes involved in the preparation of the cells.

The procedure of Planté in forming his battery is at first sight extremely simple. He takes two coils of lead, separated from one another, and immersed in dilute sulphuric acid; a current is sent through the liquid from one lead plate to the other, and the final result is that the one becomes covered with a coating of lead peroxide, while hydrogen is given off against the other plate. On the view that the sulphuric acid merely serves to diminish the resistance, and so facilitate the electrolysis of water, the ready explanation would be given that the two elements of the water are simply separated at the two poles. But it seems more in accordance with the facts of electrolysis to suppose that the sulphuric acid, H_2SO_4, is itself the electrolyte, and that the oxygen results from a secondary chemical reaction. As a matter of fact, if water be employed no peroxide is formed, but only the hydrated protoxide, even though a current from twenty-four Grove's cells be made use of. The addition of a single drop of sulphuric acid to the water is enough to cause the immediate production of the puce-colored oxide.

If we take two plates of lead in dilute sulphuric acid, and pass the current from only one Grove's cell, a film of white sulphate, instead of peroxide, makes its appearance on the positive pole, and the action practically ceases very soon. If, however, the current be increased in strength, the sulphate disappears, and peroxide is found in its place. In Planté's procedure, spongy lead and lead peroxide are indeed found on the respective plates. But in consequence of the local action which takes place during the periods of repose lead sulphate will be produced from the peroxide, and afterwards, in the course of the "formation," this must be reduced to metallic lead by the hydrogen.

It may seem at first sight improbable that an almost insoluble salt of the character of lead sulphate should be decomposed under these circumstances. To test this fact by direct experiment, we covered

two platinum plates with lead-sulphate, immersed them in dilute sulphuric acid, and sent a current through. We found not only that the sulphate was reduced by electrolytic hydrogen, but that it was peroxidized by electrolytic oxygen. The white sulphate was, in fact, decomposed to a large extent at each plate, the positive being covered with deep chocolate-colored peroxide, the negative with gray spongy lead. . . . The coating of peroxide interposes a great difficulty in the way of the further oxidation of the metallic lead. Hence Planté needs the successive periods of repose to admit by local action of the formation of lead-sulphate, and the oxidation of the increasing amounts of finely-divided lead thus brought into the field of action.

To obviate this waste of power and time, Faure covers both plates with red lead, and converts this into spongy peroxide and spongy lead, respectively, by the current. Now the first thing that happens when the plates are immersed in the dilute sulphuric acid is a purely chemical action. The minium suffers decomposition according to the formula $Pb_3O_4+2H_2SO_4=PbO_2+2PbSO_4+2H_2O$.

But as both the lead sulphate and lead peroxide are insoluble, this takes place mainly at the surface, and requires time to penetrate. Thus in an experiment performed with the object of testing this point, the following amounts of minium were found to be converted into lead-sulphate in successive periods of time:

Time.	Minium changed into sulphate.
15 minutes, . .	11·8 per cent.
30 " . .	13·7 "
60 " . .	14·6 "
120 " . .	18·1 "

It might happen, and we are told it has happened, that the amount of minium employed has been great enough to abstract the sulphuric acid from solution, leaving only water. In that case water, of course, would be the electrolyte, and there can be little doubt that the lead plate would suffer oxidation in the manner which was described by us some years ago (*Chem. Soc. Journ.*, 1876) in a paper on "Phenomena accompanying the Electrolysis of Water with Oxidizable Electrodes." This paper detailed the results obtained on passing a current from one Grove's cell between two plates of the same metal immersed in pure water. We stated in the case of lead: "The positive electrode showed signs of slight oxidation, and the negative electrode a few small bub-

bles, in fifteen minutes; a slight cloudiness was then beginning to form, which afterwards increased; some oxide was found adhering in an hour, and afterwards gray metallic lead, which at the end of twenty-two hours was found to have stretched across to the positive electrode, forming a metallic connection which was so much heated by the passage of the voltaic current that the liquid became warm." We are informed that such lead crystals have sometimes been found in Faure's cells.

Supposing, however, that there is enough and to spare of sulphuric acid, the mixture of lead peroxide and lead-sulphate presents a double problem. Were we dealing with peroxide alone, it would be reduced on the one plate at the expense of two molecules of water or sulphuric acid, while at the opposite pole the oxygen would simply be liberated. But as there is always lead sulphate present, this liberated oxygen is mainly used up in oxidating that substance, and it is theoretically sufficient to peroxidize the two molecules of sulphate. . . . These two molecules of $PbSO_4$ are also obtained from one molecule of Pb_3O_4 (red lead), and it appears that two atoms of oxygen are sufficient to transform this into peroxide. But the corresponding amount of hydrogen (four atoms) by no means suffices to reduce a similar amount of red lead on the other side, for in this case both the peroxide and the sulphate formed by the action of the acid have to be reduced. To accomplish this at least eight atoms of hydrogen will be necessary, and this will demand the electrolysis of an additional two molecules of water or sulphuric acid. It might therefore be expected, *à priori*, that the minium on the side to be oxidated ought to be twice the amount of that to be reduced.

In order to ascertain what is the real course of procedure in charging a Faure battery, we took two plates of lead of equal size, and covered each with a known weight of minium, which was almost pure Pb_3O_4. We passed a current of known strength, about one ampère, through the arrangement for many hours, noting the amount of hydrogen gas which was liberated at the one pole, and the amount of oxygen liberated at the other. From the data it was easy to calculate the amount of electrolytic hydrogen and oxygen utilized. We performed the experiment several times, varying the strength of the current and some other circumstances. The most complete result was as follows:

Time. Hours.	Hydrogen. Lost. cc.	Hydrogen. Absorbed. cc.	Oxygen. Lost. cc.	Oxygen. Absorbed. cc.
1	Nil	312	Nil	156
2	"	318	18	141
3	"	306	48	105
4	"	300	66	84
5	"	300	72	78
6	2	313	90	67
7	5	295	87	63
8	3	312	96	61
9	6	303	93	61
10	21	297	99	60
11	37	273	99	56
12	101	220	105	56
13	150	158	105	49
14	195	132	105	58
15	210	92	100	51
16	228	90	106	53
17	225	85	100	55
18	270	66	108	60
19	264	51	108	49
20	270	50	111	49
21	273	43	114	44
22	270	30	114	36
23	276	30	114	39
24	297	21	123	36
25	309	9	126	33
26	270	18	120	24
27	300	18	132	27
28	309	11	138	22
29	321	15	141	27
30	318	15	147	19
31	300	6	135	18
	5230	4489	3120	1737

The amounts of hydrogen and oxygen capable of being absorbed by the materials on the plates were 4574 and 1294 respectively.

We read the indications of this table in the following way: At first,

both the reduction and oxidation take place very perfectly, with little loss of either of the elements of water. The absorption of the hydrogen proceeds with little diminution, until by far the greater part of the lead peroxide and sulphate are reduced, but the last portions are very slowly attacked, probably because they are imbedded in a mass of reduced lead. On the side that is being oxidated it is otherwise: a considerable waste of oxygen soon shows itself, but nevertheless a continuous slow absorption of that element takes place long after the theoretical amount of it has been fixed. A very small amount of this excess is to be attributed, according to our experiments, to the oxidation of the metallic plate itself. But we attribute the greater portion to the local action which must be constantly going on between the peroxide and the lead plate, with the formation of sulphate of lead, the sulphate in its turn of course being attacked by the electrolytic oxygen. Thus the excess of oxygen in the fifth column of the above table may be looked on as a measure of the local action which has taken place during the charging, and the figures in the lower portion as roughly indicating its progress from hour to hour. Local action will of course take place at first on the opposite plate, but it requires no more hydrogen to reduce two molecules of lead sulphate than one molecule of lead peroxide, and the possibility of local action gradually diminishes as the reduction proceeds.

All our other experiments told the same story as far as the absorption of hydrogen is concerned, but there are differences on the other plate. In one or two instances not half of the theoretical amount of oxygen was absorbed. On searching into the circumstances on which this depended, we were unable to arrive at any other conclusion than that it was connected with the condition of the surface of the lead plate.

Experiments with a current of about two ampères showed that a larger quantity of both hydrogen and oxygen was fixed in a given time, but there was a larger proportionate loss, especially in the case of oxygen. Experiments with a current of about half an ampère, on the contrary, gave a somewhat less rapid action, but a smaller waste of force through the escape of free gas.

A complete study of the results of these experiments would be instructive, but the following comparisons may suffice to illustrate the points just mentioned. The theoretical amount of oxygen required for the red lead used is about 1200 cc., and the table shows the length of

time in which 300, 600, and 1000 cc. were fixed by different strengths of current, together with the accompanying loss:

Strength of current. Ampères.	Amount of oxygen stored. cc.	Time. Hours.	Loss of oxygen. cc.
2	300	1·5	174
1	"	2	18
½	"	3·8	15
2	600	4·1	617
1	"	5·5	249
½	"	7·6	47
2	1000	13·9	3081
1	"	12·2	900
½	"	16·0	400

In some cases we mixed the red lead with a little water, and allowed it to dry. In other experiments we mixed it at once with dilute sulphuric acid, but without any particular practical advantage.

The forming of a good secondary battery is a matter evidently depending upon very nice adjustment of conditions. It is but a few of these that we have carefully studied; nevertheless, we feel ourselves in a position to make one or two suggestions in regard to the economic aspects of the question. It is evident that the energy stored up in a cell is determined mainly by the amount of peroxide present. This appears to be obtained with the smallest amount of waste when the current is not too strong; in fact, in our experiments it was obtained when the density of the current was about 6½ ampères, calculated on the original surface of the lead plates.

There would seem to be no commensurate advantage in continuing the current after the oxygen has ceased to be absorbed pretty freely, because the presence of some unoxidized sulphate of lead, although it increases the resistance, rather impedes than promotes local action.

On the other hand, however, it is necessary that the reduction of the minium on the opposing plate should be complete, for a mixture of lead peroxide and metallic lead would be peculiarly conducive to the production of lead sulphate, and thus increase the resistance; while if any peroxide should remain, it would diminish the electromotive force of the cell.

It would appear probable, therefore, that the most economical arrangement would be obtained by making the red lead to be hydro-

genated much smaller in amount than that to be oxidated. On trying the experiment with only half the quantity, we obtained a most satisfactory result as far as the charging was concerned. How far such an arrangement may be really desirable we will consider more fully when we treat of the chemistry of the discharge.

Part III.—The Discharge of the Cell.

The two plates of a Planté or Faure battery consist essentially of lead peroxide as the negative element, and metallic lead in a spongy condition as the positive. These are brought into communication with one another through the lead plates which support them, together with the connecting wire.

The lead peroxide reacts both with the lead plate that supports it, and with the lead on the opposite plate. At first sight, it might be expected that the reaction between it and the supporting plate would be the greater, as the space between them is so small, and the resistance of the intervening liquid in consequence almost inappreciable. The action is, indeed, probably greater at the first moment, but, as explained in our first chapter, sulphate of lead is immediately produced, and that which lies at or near the points of junction forms no doubt a serious obstacle to further local action, and admits of the lead on the opposite plate coming more fully into play.

If we consider *à priori* what is likely to be the reaction between lead peroxide and lead, with water as the connecting fluid, we should expect: $PbO_2 \mid H_2O \mid H_2O \mid Pb = PbO \mid H_2O \mid PbH_2O_2$.

On experiment this is found to be actually the case, yellow oxide appearing on the negative plate, and white hydrate on the positive.

If, however, the reaction takes place in presence of dilute sulphuric acid, the result will inevitably be sulphate on both sides, for even if oxide be first formed, it will be attacked by that acid. Of course this production of lead sulphate on each side might be expected gradually to produce a perfect electrical equilibrium. This, in fact, does take place under certain circumstances, but not under others. The reaction on the negative plate is always of this character, as far as our analyses have shown. We have invariably found the deposit to consist of sulphate of lead mixed with unaltered peroxide. If, however, the cell be allowed to discharge itself rapidly, the lead on the positive plate is converted, not only into the sulphate, but, very partially, into lead peroxide. This is sometimes evident to the eye from the puce color of

the superficial layer, and we found also that this was confirmed by several chemical tests.

It is difficult to conceive how the reduction of the peroxide of lead on the one plate to oxide or sulphate should be attended by a direct oxidation of lead on the other plate up to peroxide itself, as that would involve a reversal of the electro-motive force. It is more easy to imagine that the peroxide results from the oxidation of sulphate of lead already formed, through the agency of electrolytic oxygen.

When this peroxide is formed on the positive plate it is not difficult to foresee what must happen. A state of electrical equilibrium will be approached before the peroxide of lead on the negative plate is exhausted. But the two sides are in very different positions with regard to local action. On the negative plate, the peroxide being mixed with a great deal of lead sulphate, it will suffer decomposition only very slowly through the agency of the supporting plate, but the lead peroxide on the positive plate, being mixed not only with lead sulphate, but with spongy metallic lead, will be itself speedily reduced to sulphate. Hence, on breaking the circuit, when local action alone can take place, the peroxide formed on the positive plate during the discharges will be destroyed much more easily than the original peroxide on the other plate. The difference of potential between the plates will be restored, and on connection the cell will be again found in an active condition.

Now it has been frequently observed that partially discharged accumulators do give an increased current after repose, that is, after the circuit has been broken and re-established. It remained for us to ascertain whether the chemical change above described coincided in any way with the physical phenomena. For this purpose we prepared plates according to the method of Faure, and examined carefully the changes of electro-motive force and strength of current, which took place during their discharge under known resistances, and the chemical changes that took place under the same circumstances.

We found that the initial electro-motive force of freshly prepared cells was 2·25, 2·25, 2·21, and 2·31, volts, averaging 2·25, but that after standing for thirty minutes or so, or when allowed to discharge for a few minutes, it was reduced to about 2·0 volts. We take this to represent the normal electro-motive force of the arrangement of lead, lead peroxide, and dilute sulphuric acid, and believe that the higher

figure obtained at the first moment is due to the hydrogen and oxygen occluded on the respective plates, and which either diffuse out or are speedily destroyed.

We found, however, that in the discharge the electro-motive force diminished under certain conditions. Thus, in an experiment in which the external resistance was 1 ohm, and the internal 0·58 ohm, the E.M.F. sank in forty-five minutes from 2·25 to 1·92, but after being disconnected for thirty minutes, it was found to have risen to 1·96, and after eighteen hours' repose it had actually risen to 1·98 volts. These observations were made many times in succession during the course of the experiment, which lasted six days.

With twenty times the external resistance, the diminution of electro-motive force was much slower ; but after discharging three days, the fall was more pronounced, and the rise on repose very apparent.

With 100 ohms resistance the electro-motive force varied very little for three days.

It is more difficult to obtain satisfactory chemical evidence of a quantitative character. It is clear that as chemical examination means the destruction of the substances, the same plate cannot be analyzed in two consecutive stages. Nor can two plates be easily compared with one another, although they have been formed under the same circumstances. Even the same positive plate, during or after discharge, presents to the eye very different appearances in different parts. To a certain extent we obviated this difficulty by cutting the plate in two, longitudinally, analyzing the one half at once, and allowing the other to repose for a given time before examining it for peroxide of lead.

As to the estimation of peroxide in the presence of metallic lead, we finally adopted as the best method that of reducing it by means of oxalic acid, although we were not certain that the whole amount is obtained in this way, even though the solution be kept hot for a considerable time.

By this method many chemical examinations were made of the positive plate. The results are as follows: First of all, when the external resistance did not exceed 20 ohms the peroxide of lead was generally visible in patches, and its presence was demonstrated and approximately measured by various chemical tests. On repose, the quantity of this peroxide visibly diminished, and in the majority of instances the chemical analyses also showed a smaller amount. In all cases sulphate

of lead makes its appearance early in the action, and gradually increases in quantity, becoming finally the only product of the discharge.

The deposit on the negative plate shows the presence of nothing but sulphate of lead in addition to the unchanged peroxide. At the conclusion of the action, we have always found more or less of this substance unaltered. Thus, as one instance, after a discharge lasting five days, and approximately complete, we found that only 68 per cent. of the deposit was lead sulphate.

We conclude, therefore, that the chemical action of the discharge is essentially what is expressed by the following theoretical formula:

$$PbO_2 \mid H_2SO_4 \mid H_2SO_4 \mid Pb = PbO \mid H_2O \mid H_2SO_4 \mid PbSO_4,$$

which becomes

$$PbSO_4 \mid H_2O \mid H_2O \mid PbSO_4.$$

This reaction is, however, sometimes complicated by the formation of a small amount of peroxide of lead on the positive plate. We believe this to be due to the oxidation of sulphate, an action which was explained in our last chapter.

Another conclusion has reference to the resuscitation of power observed on repose. This is not due to any purely physical action but is a necessary consequence of the formation of PbO_2 on the positive plate. As sooner or later the result of the action becomes solely $PbSO_4$, this temporary formation of peroxide does not seriously affect the quantity of electrical force that may be regained from the accumulator, but it does affect the evenness of its flow. The flow is more regular if the discharge be made slowly, but in that case the loss on the negative plate from local action will probably be greater.

As to the practical conclusions we may note: 1. Although, as stated in the first chapter, the most economical arrangement for the initial charging of the cell is to "make the red lead to be hydrogenated much smaller in amount than that to be oxidated," yet, as foreshadowed in the same chapter, this arrangement is not desirable for the discharge of the cell. Nor is it for its subsequent charging, since, as will have been seen, the substances to be acted upon are now very different. On the negative plate there will be the sulphate of lead produced by the discharge, plus sulphate of lead produced by local action, together with more or less unaltered peroxide. On the positive plate there will be the sulphate of lead produced by the discharge, together with excess of lead, if any. Unless, therefore, the peroxide of lead unacted upon is allowed to be very considerable, the quantity of lead compound on the two sides ought to approach equality. 2. Care should be taken

that sulphuric acid is in sufficient excess to allow of there still remaining some of it solution after all the available lead has been converted into sulphate. If it is removed and only water is present, an oxide or hydrate will be produced with probably some serious consequences to the cell.—*London Nature.*

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

THERMOSTATIC CUT-OUT FOR ELECTRIC LIGHTING SYSTEMS.—This recent improvement combines with the main conductor of an electric lighting system a switch constructed and arranged to electrically connect the main conductor with the electric conductor of a building. When, however, the temperature of the electric wires extending through the building exceeds a predetermined degree, the switch automatically short-circuits the current through the main conductor. This effect is accomplished by a wire connected to the switch-lever and extending through the building, connected, or joined, at intervals by fusible joints or links. A weight is provided for shifting the switch and short-circuiting the current upon the fusion of the joints or links.

RAILWAY SNOW PLOW—A late invention comprises a car or truck which carries two vertical and two horizontally-inclined endless aprons with supporting rollers, by which the snow is carried up and compressed, the upper horizontal apron being adjustable in inclination to regulate the amount of compression to which the snow is submitted. All of the aprons are driven by rods and gear wheels from an engine, mounted upon the truck, and are supported and adjusted by ropes and tackle from an upright frame on the car. The snow is divided and directed onto each of the aprons, and prevented from falling between them by an angle board above the adjoining ends. To the front of the car is a funnel with its sides flanged to lap the top and bottom plate. To the front of the funnel is a reciprocating cutter-bar driven out by an angle-lever and crank-wheel from the apron roller-gearing.

INCANDESCENT ELECTRICAL ILLUMINATION.—In this improvement illuminated signals, symbols, designs, or figures are composed of electrical conductors bent or formed into the required shape, and having numerous electrical vacuous cells removably attached or connected thereto. The conductors of the electric circuit are formed of suitable

material, having considerable body, and running horizontal and parallel to each other. These conductors have cavities or depressions therein, or grasping devices attached thereto, located opposite each other so as to hold incandescent electric lamps or vacuous cells in electrical connection.

ELECTRIC LANTERN.—This novel lantern is composed of wire frame-work of similar contour to the ordinary oil lantern. The upper part of the frame supports a secondary battery, and an incandescent lamp is supported directly below. Electrical connections for charging the battery, and similar connections between such battery and the lamp, are provided. There is a bail for carrying the lantern, and a removable top to give access to the battery.

STOP-COCK.—In this improved cock or faucet an interior elastic flexible tube is provided, and an opening is cut away in the exterior metal tube to expose a portion of the flexible tube. A lever having a depending stirrup, arranged to compress the elastic tube, is employed so as to stop the flow of the liquid. The lever, for this purpose, is eccentrically pivoted to a hand-operating lever, suitably journaled in bearings cast on the cock.

RAILWAY TRAIN TELEGRAPH.—This apparatus is designed for telegraphic communication between a number of moving trains and any number of intermediate stations. It employs two suspended insulated main wires—one wire connected at one end with one terminal battery, and the other wire at its opposite end with another terminal battery—in combination with a traveling truck or sheave, connected electrically with the moving train, and in contact with the main wires, and having inleading and outleading wires. The main wires are severed at the stations, and connecting wires from the severed ends pass to the instruments in the stations and are connected with each other by switch-boards.

AUTOMATIC TELEGRAPH TRANSMITTER.—This device is designed for learners' use. A prepared strip perforated with messages is inserted into the instrument and carried under a transmitting-stylus, which automatically makes and breaks a circuit through a reading sounder. Should the student fail to correctly read any letter or word he presses a lever, and thereby causes the motor to reverse the reel, lift the stylus, and rewind the transmitting strip, after which, on reversal of the lever the message or word is repeated.

Washington, D. C. FENELON B. BROCK.

Crayons in Vitrifiable Colors.—M. Lacroix, a Parisian chemist has introduced crayons similar to the ordinary lead pencils, the lead being replaced by vitrifiable colors. The colored designs which are executed with these crayons, on slightly roughened glass, bear the heat of a muffle and are fixed like a painting upon glass; the grays especially give excellent results. A similar process which was tried upon porcelain some years ago was unsuccessful, probably because enamelled surfaces were used. On biscuit it is likely that good results might have been obtained.—*Chron. Industr.*, No. 21, p. 257. C.

Crumbling of Tin.—Leaves of tin foil, when they are exposed for a long time to cold, sometimes become brittle, fall in pieces, and are finally reduced to powder. Fritzche and Lewald have spoken of a crystalline texture which the metal takes under the influence of cold. Prof. Rammelsberg has suggested the idea of a stannic dimorphism, basing his views upon examinations which disclosed a diminution of specific weight in the crumbled tin. Oudemans and Walz cite a case in which good commercial tin, with the usual quantity of 3 per cent. of lead, was changed into a gray powder during the transit from Rotterdom to Moscow in a very cold winter. In discussing this observation M. Wiedman calls the attention of physicists to the probable influence of continuous vibrations, such as would result from variations of temperature. Another remarkable fact shows that the phenomenon may be produced by continuous small shocks. In a corner of a window in the cathedral of Fribourg there was found a wooden box which, when it was opened, disclosed fragments of a medal and of a tin ring, as well as small bits of a reddish-gray color, of the remarkably low specific gravity of 5·8. In this case, as well as in those already mentioned, a metal having the brilliancy, the specific weight, and the other ordinary qualities of tin, could be obtained by simply heating the debris at the temperature of boiling water. M. W. Markownikoff, of Moscow, gives an account of some tin pots which were left in a cold room of one of the government buildings, on which swellings first appeared, then holes, and then there was a gradual crumbling to powder. When once begun the destructive action cannot be stopped by carrying the pots into a warm room, but it ceases by removing the parts which are attacked.—*Les Mondes*, May 20, 1882. C.

Economical use of the Falls of the Rhine.—In Switzerland, a number of citizens of Schaffhausen are disposed to utilize the transmission of the mechanical force of the falls by dynamo-electric machines. Already several of these machines, which were built at Basle by Burgen and Alioth, have reached Schaffhausen, and two of them are in constant use. The mechanical force of a wheel, which is set in motion by the water, is transformed into electricity and conveyed to a distance by thick copper wires, in order to be transformed again into mechanical force at its destination.—*La Lumière Electrique*, vi, 359.

To Distinguish Cotton-seed Oil from Olive Oil.—Prof. Zecchini takes pure colorless nitric acid of the density 1·40, and mixes it with half the quantity of oil in a tin tube closed with gum. After shaking it for several seconds the tube is allowed to rest in a vertical position for 5 or 6 minutes. If the oil was from olives the liquid is at first pale or colorless, changing to an ashy grey with a slight yellowish hue. Cotton-seed oil is at first of a golden yellow, then copper-colored, becoming almost black. The reaction is delicate enough to detect an adulteration of 5 per cent. of cotton-seed oil.—*Les Mondes*, May 13, 1882. C.

Treatment of Silver Ore.—A. Raimondi gives the following reactions in the Peruvian treatment of silver ores: 1. After adding chloride of sodium a flux is introduced which is composed principally of sulphate of copper, giving the following reaction:

$$CuOSO_3 + NaCl = CuCl + NaOSO_3.$$

2. The chloride of copper which is thus formed reacts upon the mercury and upon the silver, both in the metallic state and in their combinations with sulphur, as follows:

$$2CuCl + Hg = Cu_2Cl + HgCl,$$
$$2CuCl + Ag = Cu_2Cl + AgCl,$$
$$\begin{cases} 2CuCl + AgS = Cu_2Cl + AgCl + S \\ CuCl + AgS = CuS + AgCl. \end{cases}$$

The action of the cupric bichloride upon the mercury is more rapid than upon the silver; the reactions upon the silver are more or less intense, according to the chemical state of the metal and the proportion of cupric chloride. The presence of salt is not indispensable for the actions of the chloride upon the argentiferous compounds, but it appears to facilitate them. Perchloride of iron may be substituted for the cupric chloride, but it is less efficacious.—*Ann. des Mines.* C.

Extension of Mariotte's and Gay-Lussac's Law.—Biehringer gives the following formula:

$$\frac{p\,s\,v}{q} = \frac{p's'v'}{q'} = \text{const.}$$

In this equation p denotes the pressure, s the specific gravity, v the volume, q the absolute weight of a gas; $p's'v'q'$ are the corresponding values for any other gas, and the constant remains unchanged as long as the temperature of the gases is the same. He gives a modification of the formula which is an algebraic expression for the following laws: 1. Gases whose densities are proportional to their specific gravities exert equal pressures at equal temperatures 2. Gases with equal densities exert pressures at equal temperatures which are inversely proportional to their specific gravities. Instead of the density the absolute weight and volume may be introduced for deducing further laws.—*Beiblätter*, vi, 207. C.

Regenerating Battery.—J. Rousse replaces the zinc of the Bunsen cell by ferromanganese, of the strength of 85 per cent. Pure manganese has such an affinity for oxygen that it decomposes boiling water. This gives to the new battery an electro-motive force similar to that of amalgamated zinc. In order to produce energetic currents diluted sulphuric acid is employed; the depolarization is obtained by concentrated nitric acid. For feeble currents, and when the battery is to be employed in ordinary apartments, permanganate of potash is employed as a depolarizer. The salts produced by the battery are sulphate and nitrate of manganese or of potash. To remove the sulphuric acid from the liquid he treats it with the nitrate of lead, which is produced in his lead battery. The sulphate of lead which results from this reaction is transformed into ceruse, by boiling with carbonate of potash. The soluble salts separated by decantation contain only nitrates of manganese and of potash. Pouring in carbonate of potash all the oxide of manganese is precipitated in the state of carbonate. This precipitate is washed and calcined, to reduce the metal to a sesquioxide, which is heated with potash and nitrate of potash and thus transformed into permanganate of potash. Peroxide of manganese is then easily obtained by known methods. All these chemical operations are simple and can be easily executed; they are so combined as to produce dynamic electricity economically and without leaving useless residues.—*Comptes Rendus.* C.

Meteoric Organisms.—Carl Vogt has carefully examined the peculiar formations which were found in meteorites by M. Hahn, in order to satisfy himself whether their structure is organic. By a detailed comparison with living and fossil sponges, corals and crinoids, he arrives at the conclusion that the forms are entirely inorganic. He thinks that they are due to the presence of an opaque incrusting material, aided by optical illusions which arise from an incomplete method of microscopic research. His observations go to show that the figures are all composed of transparent crystalline fragments, arranged in various ways, but most commonly in columns, or tufts, ramified or radiating from a centre. The interstices are filled with an opaque substance which is but slightly affected by acids, and which mimics organic structure. These views, however, are still disputed by Hahn and other European and American microscopists.—*Comp. Rend.* C.

Tempering by Compression.—L. Clémandot has devised a new method of treating metals, especially steel, which consists in heating to a cherry red, compressing strongly, and keeping up the pressure until the metal is completely cooled. The results are so much like those of tempering that he calls his process tempering by compression. The compressed metal becomes exceedingly hard, acquiring a molecular contraction, and a fineness of grain, such that polishing gives it the appearance of polished nickel. Compressed steel, like tempered steel, acquires the coercitive force which enables it to absorb magnetism. This property should be studied in connection with its durability; experiments have already shown that there is no loss of magnetism at the expiration of three months. This compression has no analogue but tempering. Hammering and hardening modify the molecular state of metals, especially when they are practiced upon metal that is nearly cold, but the effect of hydraulic pressure is much greater. The phenomena which are produced in both methods of tempering may be interpreted in different ways, but it seems likely that there is a molecular approximation, an amorphism, from which results the homogeneity that is due to the absence of crystallization. The advantages of the new method are obvious. Being an operation which can be measured, it may be graduated and kept within limits which are prescribed in advance; directions may be given to temper at a specified pressure as readily as to work under a given pressure of steam.—*Chron. Industr.* C.

Book Notices.

THE CIVIL ENGINEER'S POCKET BOOK. By John C. Trautwine, C.E. Seventeenth Thousand. 12mo, 693 pages. Philadelphia: E. Claxton & Co. 1882.

We have before us another edition of this valuble technical text-book, by far the most useful pocket book for the civil engineer which has yet been published, containing a vast amount of information on surveying, hydraulics, hydrostatics, instruments, strength of materials, roof and bridge trusses, railroads, etc.; deductions from complicated and abstruse formulæ, experiments and practice condensed into a portable and convenient form, from a vast number of volumes of technical literature, as well as from the results of the author's practice during a long and active professional life.

Among the additions will be found a table "To find circumfs of circles when the diam contains decimals," on page 675; other additions will be found throughout the work, as well as the correction of such errors as have been noticed in previous editions.

In conclusion, we can only say that this work, while indispensable to the young civil engineer, will also be found of much use by the more experienced members of the profession. C. H. R.

THE FIRE PROTECTION OF MILLS AND CONSTRUCTION OF MILL FLOORS. By C. J. H. Woodbury, M.E., Inspector Factory Mutual F. I. Companies. New York: John Wiley & Sons. 1882.

A practical application of certain neglected means and recent improvements to the protection of factories, etc. Water supply, standpipes, tanks, pumps, valves, hose and general organization for service are first treated. The author illustrates an admirable mode of *grooved* large and small pulleys for driving pumps—the smaller pulley moved into gear by a screw. This plan removes all fear of broken or slack belts at a critical moment. Automatic sprinklers are described, with full sized designs of heads; also tinned wooden "fireproof" and automatic closing doors. Mill fires, spontaneous ignition and electric lighting have a large share of the discussion, and illumination by electricity is expected to become very general in mills. Heating, fires caused by steam pipes and lanterns, the spontaneous ignition of goods in dye-houses, together with modes of self-insurance by factory owners, close what may be called the first part of this excellent handbook.